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Separate Collection of Bio-Waste in General Areas of University Centers

Verónica Torrijos, Martina Dono, Manuel Soto*

Universidade da Coruña, Office for the Environment, Ed. Xoana Capdevielle, Campus de Elviña, 15071 A Coruña, Spain.

*corresponding author: v.torrijos@udc.gal

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Abstract. Traditionally, the separate collection of different fractions of waste in university centers was limited to the collection of paper/cardboard and packaging waste, while the collection of bio-waste was introduced only for dining and cafeteria services. It was based on the consideration that in general areas of the centers, such as classrooms, corridors, administrative areas, or offices, organic waste was not generated. However, eating habits and lifestyles have been changing and food remains becoming more frequent in these areas. The inspections carried out in the UDC in 2015 showed that 25% of the waste belonged to the bio-waste category, and subsequent inspections indicated that in some cases it may constitute the main waste fraction. Having verified this fact, the conclusion was that the intra-center waste segregation model should be revised, introducing a specific collector for bio-waste in all areas of the university centers. This communication describes the separate collection model and presents the results achieved in five centers of the UDC. The results achieved were very positive, approaching or exceeding in most cases the threshold of 85% correct content in the bins, a value that is considered minimum to classify it as a separate collection for quality recycling. The capture of materials for recycling exceeded 70% of the waste generated.

Keyword:
Waste Separation Model, Bio-Waste, Preparation for Recycling, Students Involvement

Acronyms

Waste type acronyms: PC: paper and cardboard; G: glass; OFMW: Organic fraction of municipal waste or bio-waste; NOFMW: Non-Organic fraction of municipal waste or dry fraction; WEEE: Waste from Electrical and Electronic Equipment; OW: other waste, ODW: other dry waste planned to be collected in the NOFMW stream.

Center acronyms: FP: Faculty of Philology. SA: School of Architecture. FS: Faculty of Science. STA: School of Technical Architecture. FS&CS: Faculty of Sociology and Communication Sciences. FES: Faculty of Education Sciences. SE: School of Engineering. FCS: Faculty of Computer Science. FEB: Faculty of Economy and Business. FL: Faculty of Law.

1. Introduction

Several ODS2030 are related to the problem of waste, its production and its management. Directly the ODS goal nº 11.6 "sustainable communities: management of municipal waste" and nº 12.5 "responsible production and consumption: significantly reduce the generation of waste through activities of prevention, reduction, recycling and reuse" [1]. While the correct management and recycling of waste is a first step towards a more circular economy [2], the reality shows that, even in universities, a large proportion of recyclable materials are still sent to landfill or incinerated [3]. However, there are opportunities for improvement, as reported by Fagnani and Guimarães [4], who achieved great reductions of recyclable materials in waste through awareness campaigns. The separation at the source and its quality is important for the preparation for recycling of all fractions, and especially for the organic fraction with the aim of obtaining good quality organic fertilizers or compost [5,6].

While the EU target for urban waste recycling by 2030 has been set at 60%, in Galiza, the geographical area of the University of Coruña (UDC), it is currently below 20% [3]. Following the first waste management plan of 2013, the UDC achieved 25% selective collection of urban waste for recycling. At the same time, a decentralized composting program was developed for the organic waste from the university canteens [5], which lead to an improvement in the overall recycling figures. However, apart from paper and cardboard, batteries and printing cartridges, the internal segregation of other types of waste in the general areas of the UDC did not start until 2017.

The aim of this work is to revise the traditional waste collection model at the UDC, identifying the need for separate collection of organic matter produced by the university community in the general areas of the centers. This paper describes the new separate collection model and presents the results achieved in the first five centers of the UDC.

2. Materials and Methods

This study corresponds to 7 teaching centers in the main campus of the UDC, Elviña-A Zapateira, a peri-urban area of A Coruña. This area represents about 65% of the total university community, with 14,115 people (12,110 students, 2,001 employees) in 2023. The total number of teaching centers was 10, while other 10 were dedicated to research and administrative services.

Waste management practices are related to the stipulations of the municipal service. This provides waste containers, transport and treatment for some categories such as paper and cardboard (PC), glass (G), organic fraction of municipal waste (OFMW) (i.e. bio-waste), and non-organic fraction of municipal waste (NOFMW) (i.e. dry fraction). Thus, NOFMW includes packaging waste, as well as any other type of waste not subject to a specific collection line. Available information indicates that packaging waste was efficiently recovered from the NOFMW stream at the municipal treatment plant [7]. Other features of the municipal treatment plant are available [7].

The waste concerned in the present study corresponds to those streams collected by the building cleaning service of the centers and directed to the municipal waste management service. Therefore, waste from the canteen and reprographics services or other waste streams with specific management channels were not included. The information managed was obtained from inspection campaigns carried out by OMA with the participation of scholarship students and volunteers.

Taking as reference this wet-dry municipal separation model, containers for the OFMW were restricted to points linked to catering services, while in other areas of the buildings only PC was separated from the rest of the waste fractions. This was due to the consideration that, apart from catering services, glass and organic waste was not generated to any significant extent in the rest of the university areas. As described in this paper, this consideration was discarded after 2017 when the use of bins for bio-waste (OFMW) started and progressively extended to most of the buildings.

Mixed waste characterization

The work protocol was as follows. The rubbish collected by the cleaning service for a week (5 school days in a row) was stored in a suitable place in the same bags in which it was collected. To facilitate the sorting and weighing process and to avoid possible odors, the sorting and weighing work was carried out twice a week. In this way, generation and composition data were obtained in the accumulated period of 5 days, and disaggregated data for periods of 2 and 3 days. For each of the periods, each bag was separated into waste fractions and each fraction was weighed. The following waste fractions were considered: PC, G, OFMW, plastic bottles, cans (mostly aluminum cans for soft drinks and canned food), liquids contained in bottles and cans, and, finally, OW.

Waste characterization for the selective collection model

The quality of selective collection for PC, OFMW and NOFMW streams in the new sorting model tested in some centers from 2017 onwards was regularly determined on-site during information and awareness campaigns such as the European Week for Waste Reduction (EWWR). For this purpose, the cleaning service was asked to empty all bins in the building on the same day and not to empty them for the following two days (or up to 5 days in some cases of very low generation). After this period, the working group (technical staff, scholarship students and volunteers) proceeded to collect, separate by material type and weigh the contents of each waste container. The characterization campaigns also aimed to train and sensitize the participants and the university community in general about the separation of waste, making use of the information obtained. For this reason, the campaigns had more continuity in some centers than in others, which sometimes led to partial or discontinuous results. From the information collected, the appropriate material content rate (percentage), the correct capture rate (percentage) and the generation rates of each fraction (kg/d) were obtained.

3. Results

3.1. Management model and evolution between 2013 and 2017

The waste management plan of 2013 (Fig. 1) made a diagnosis of the starting situation and identified the necessary measures and means to improve management and achieve higher recycling percentages. The waste stream handled by the cleaning service is identified in Fig. 1 as NOFMW, corresponding to a mixed waste stream. A characterization campaign was carried out in the 10 teaching centers in 2014. The per capita generation rate of NOFMW varied widely in the range of 5 to 27 g/capita·day, showing clearly higher values for some of the centers (highest for the Faculty of Sciences, followed by the Faculty of Education Sciences) than for others. The students staying longer in these centers throughout the day could explain this. A tendency to reduce the generation rate was also observed depending on the number of people using the center. This explains the difference between the average rate (7.5 g/capita·day) and the average of the different centers (11.4±6.5 g/capita·day). Total generation was 905 kg NOFMW/week during the ordinary academic activity period.

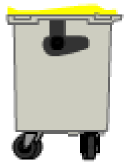
Fraction (options I and II)	OFMW (canteens) I	OFMW (canteens) II	G (canteens)	PC (all center areas) I	PC (all center areas) II	NOFMW (all center areas)
Container type						
Destination	MS	UDC campus composting areas	MS	MS	MS	MS

Figure 1. Management model adopted in 2013 for the UDC central campus (MS: to municipal service)

The four materials identified separately (PC, plastic bottles, metal cans and glass bottles) contributed 36.9% of the waste generated, being the remaining 63.1% due to the other fractions. Among the first ones, their quantitative presence was as follows, from greatest to least: PC (23.7%), plastic bottles (6.8%), metal cans (5.3%) and G (1.2%). The presence of these fractions in the different centers was uniform for bottles and cans, while for PC varied from 3% to 63%. Despite that all centers had containers for paper segregation (Fig. 1), a very different efficiency for the PC collection was found. In these years, only the FS&CS model was efficient, reducing PC in the NOFMW stream to 2.5%, while in most centers reached between 10 and 40%.

Thus, with respect to the fraction of PC, the extension of the model previously experienced in FS&CS was proposed, consisting of locating an abundant number of small PC containers per plant (intra center separation of PC; option II in Fig. 1). This option was implemented in two UDC centers in 2015, SA and STA, where PC recovery was improved. The 2015 characterization study, conducted at four centers on the central campus, showed that the waste PC content in the NOFMW stream dropped to 11.2%, compared to 29.7% in 2014. This reduction reflected the impact of attention to waste management, including communication campaigns to the university community. In the two centers where the PC collection model was changed, the presence of PC in NOFMW decreased from 63% and 23% in 2014, to 17% and 4.5% in 2015, for STA and SA, respectively.

With regard to OFMW, efforts focused on expanding the on-site composting of bio-waste generated in university canteens (option II, Fig. 1). The on-site composting program was progressively completed until it reached 9 composting areas in 2020 that took care of most of the bio-waste generated in the university canteens. The efficiency and quality of the separate collection of bio-waste in the canteens and its transformation into high-quality compost allowed the consolidation of the composting program, which reached the transformation of 48 t of bio-waste in 2020 [3,5].

As noted in the M&M section, the 2014 characterization allowed comparison of both generation rates and composition obtained at 2-, 3-, and 5-day accumulation periods. Good correlation between the generation rates obtained in the 2-day and 3-day accumulation periods versus the generation rate for the 5-day period (a full week) was found (R^2 of 0.90 and 0.95 for 2d and 3d, respectively, at a probability level of $p<0.01$). Regarding the composition, significant correlations (R^2 from 0.67 to 0.94, $p<0.01$) between the percentages obtained in the reduced periods of 2d and 3 days with the percentages obtained at 5 days were also obtained for all fractions (except glass, due to the very low generation rate of this material, which showed a percentage lower than 1.2%). A two-factor analysis of variance with a single sample per group indicates that the means obtained in each sub-period are not different from each other ($p>0.05$). Therefore, we concluded that the accumulation of the waste generated for 2 or 3 days and its characterization was sufficient to determine both the generation rate and the composition and therefore the degree of separate collection that occurs. This also facilitates frequent characterization campaigns with the involvement of scholarship students and volunteers and the use of the information gathered for outreach and awareness activities.

3.2. The quality of separate collection in centers with the new OFMW-NOFMW-PC model

The results from 2011 to the present indicate that the presence of bio-waste in the centers has been increasing over time, according to the following percentage trend: 9.0% (2011, n=10), 14.7% (2015, n=5), 24.4% (2019, n=4), 33.3% (2021, n=5), being n the number of centers included in the study. Even higher values were recorded in the 2020 characterizations after the outbreak of COVID-19, reaching values of 40-45% of OFMW in three centers where the value of 2019 more than doubled (SE, from 13.8% to 45.4 %; STA, from 17.4% to 43.9%; FES, from 19.0% to 40.2%). This was the reason why the selective collection of bio-waste was introduced after 2017.

In a first center (FES), in 2017, PC/OFMW/NOFMW separate collection points were created based on the use of 120L containers for PC, and the use of the existing "trash bins" identified with a green (FORM) and yellow (NOFMW) bag, as shown in Fig. 2a. These separate collection points were spread throughout all the corridors and areas of the center, with the gradual removal of bins in classrooms and voluntarily in offices. In another center (SE), PC/OFMW/NOFMW separate collection points were formed with properly identified cardboard boxes of 90L (Fig. 2b). In both cases, these separate collection points were completed with a clean point that allowed the collection of other waste, such as glass, WEEE, oil, batteries, printing waste, etc. (Fig. 2c). Later, this separate collection model was adopted in other centers: one in 2019 (STA) and four in 2021 (FS, FEB, FL and SNS), after the end of the confinement periods due to COVID-19. Below we describe the evolution in FES and the results achieved with this model, using data from three centers in 2019 and five centers in 2021.

Figure 2. Images PC/OFMW/NOFMW separate collection points in FES (A) and SE (B), and general clean point in ES (C).

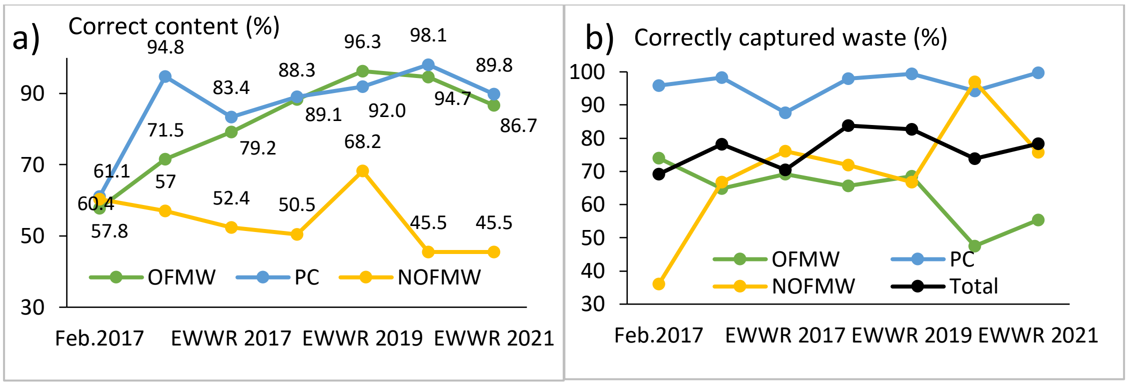


Figure 3. Evolution of separate collection in PC/OFMW/NOFMW separate collection points in FES (EWWR: European Week for Waste Reduction, held at November of each year).

The implementation of the model in the FES did not initially give the expected results, since the correct content index were around 60% for the three fractions of waste, which meant a slight improvement over the undifferentiated collection (Fig. 3a). Throughout 2017, information campaigns were intensified in the center, with exhibitions, workshops, communication to e-mail lists and mini-talks in classrooms (5 minutes) in which the model of separation was explained. This led to a progressive improvement of the results, achieving correct content indexes in the range of 83-98% for PC and 80-96% for OFMW, remaining below 60% for NOFMW. Global capture for recycling of waste affected by the model (in implementation areas) increased over time from 70% to 83% (2018, 2019), being reduced again to 74% in November 2020 due to the impact of COVID-19 (Fig. 3b).

The models implemented in the SE and the STA gave more positive results from the beginning, even superior to the best of the FES (Fig. 4), and having required less information activity. The correct content index was between 80% and 97%, for the three waste streams. The PC capture rate was 98.6-99.8% across all three centers in November 2019, so virtually all PC in this model was collected for recycling. The total capture depends on the capture of each container, but also on whether the system covers all areas of the building or only a part. The 2019 data offer a lower capture for SE (72%) due to the fact that the teachers did not use the system but the single bin at offices, and due to the non-separate collection of waste in toilets. In the other two centers, the overall capture exceeded 80%.

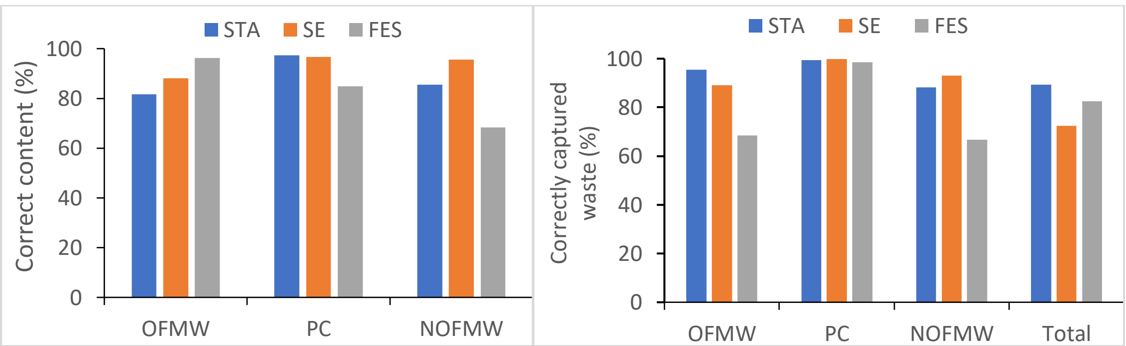


Figure 4. Correct content and correctly captured waste indexes in November 2019 at three centers (FES, SE, STA) with PC/OFMW/NOFMW separate collection points.

Fig. 5 shows the results achieved for the 4 new centers (SNS, FS, FL and FEB) in 2021, together with those of the FES center. The separate collection quality for these five centers in 2021 offered average correct content indices of 88.2 ±10.3% for OFMW (range 74–97%), 81.3±8.6% for PC (range 71–90%) and 70.4±17.6% for NOFMW (range 45–90%). On the other hand, the sum of materials collected in the correct bins was 62.9±15.4% (range of 52-86%), 99.0±1.1% (91-100%) and 80.0±6, 6% (71–88%) for OFMW, PC and NOFMW, respectively. The difference between centers is not notable, with the worst quality being recorded for the NOFMW flow in FES and the largest captures of OFMW in FS and FEB.

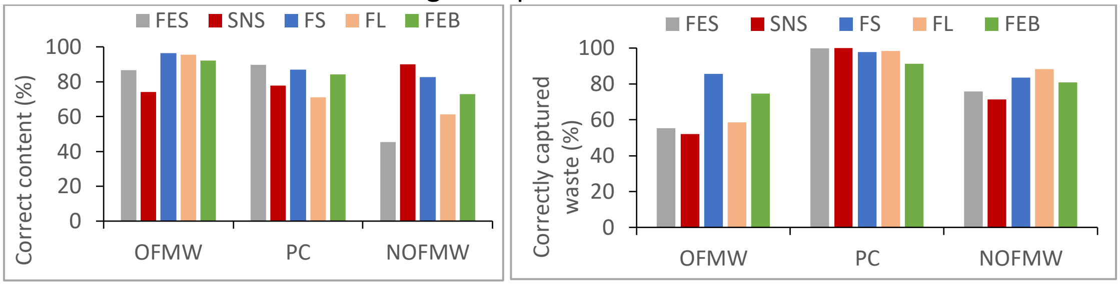


Figure 5. Correct capture and correct content indexes in November 2021 (FEB: May 2021), at five centers with PC/OFMW/NOFMW separate collection points.

Fig. 6 shows the composition of the waste generated in the general areas of the five centers in 2021, characterization made by the scholarship and environmental volunteers of the university. This activity included the study of waste collected at PC/OFMW/NOFMW collection points, at the general clean point of each center, and at areas of the center that did not have yet separate collection. The results verified the low presence of glass (average of 1.4%). People using the general areas of the centers have a clean point at the main entrance of each one where they can deposit the glass bottles (Fig. 2c), and also other types of waste subject to special collection (such as WEEE, medicine containers, batteries, bottle caps, etc.). These types of materials appeared at 1% on average in these centers. The three target fractions PC, OFMW and NOFMW, appear in very similar proportions, each contributing 32-33% of the total waste generated in the general areas of the centers, adding together 97.6% of the total waste (Fig.7).

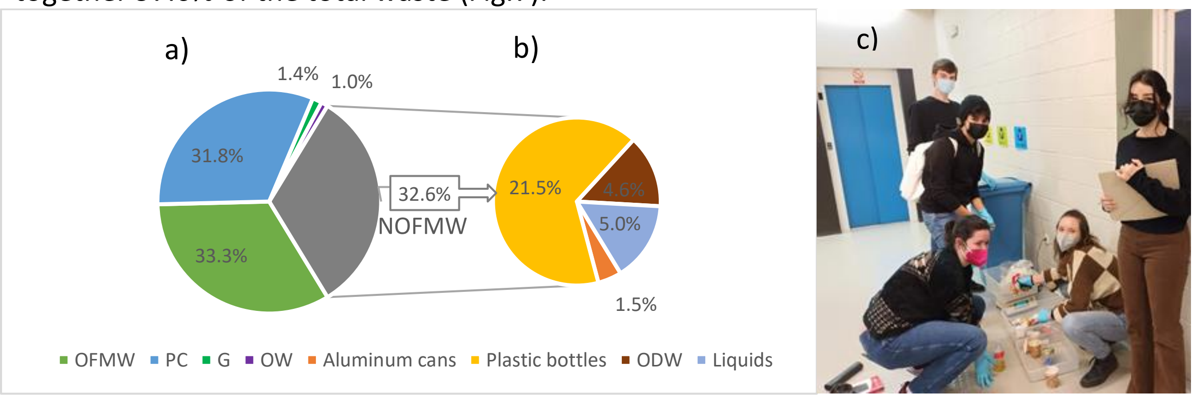


Figure 6. Average composition obtained from the inspection of five centers of the UDC (2021). a) Main flows of waste planned to be segregated at source, b) Breakdown of the composition of the dry fraction, NOFMW. c) One group of scholarship students and environmental volunteers of UDC at waste characterizations

Of these three fractions, NOFMW constitutes a mixed waste that the municipal plan seeks to collect in a single container for classification at destination. Most of it is light recyclable packaging, as plastic bottles and metal containers (aluminum) add up to 23% of the total waste and 70.5% of the NOFMW stream. Note that is frequent the presence of liquids, mainly water, inside used bottles, in this “dry” fraction, reaching the 5.0% of the entire total waste generated and (15.4% of NOFMW). Finally, 4.6% of the waste (14.1% of the NOFMW flow) corresponds to other types of waste that must be collected in this dry fraction (ODW), and that do not correspond to light packaging. Part of them can be considered non-recyclable in the current model. Finally, the results confirmed the increase in the organic fraction, already observed in previous years. Globally, the sum of the recyclable fractions reached 95% of the waste generated.

4. Conclusions

The results of this work confirmed the increase in the organic fraction in the waste generated in the general areas of university centers during the last decade, currently reaching more than a quarter of the total waste. On the other hand, the sum of the recyclable fractions reached at least 95% of the waste generated, indicating the need and convenience of waste segregation at source. The collection model with PC/OFMW/NOFMW separate collection points adopted at UDC centers had very good results, with correct content generally above 80% in all three streams. The separate collection of bio-waste in the general areas of the teaching centers made it possible to capture more than 50% of the quantities generated with sufficient quality for conversion into high quality compost. On the other hand, the very high capture of PC stands out, generally around 99%, much higher than that allowed by the previous model, although the quality of it was somewhat resented. Overall, the results achieved in the centers with the new separate collection model were very positive, but it is necessary to continue with information and awareness campaigns on the separation of waste at source. Finally, but not least, it is worth highlighting the educational value of the waste campaigns aided by scholarship students and volunteers, which take advantage of the most direct way of transmission, from students to students.

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