THE DETERMINATION OF WASTE GENERATION AND COMPOSITION AS AN ESSENTIAL TOOL TO IMPROVE THE WASTE MANAGEMENT PLAN OF A UNIVERISTY.

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Abstract

When many people work in organized institutions or enterprises, those institutions or enterprises become big meeting places that also have energy, water and resources necessities. One of these necessities is the correct management of the waste that is daily produced by these communities. Universities are a good example of institution where every day a great amount of people go to work or to study. But independently of their task, they use the different services at the University such as cafeterias, canteens, photocopy etc. and as a result of their activity a cleaning service is also needed. All these activities generate an environmental impact. Nowadays, many Universities have accepted the challenge to minimize this impact applying several measures. One of the impacts to be reduced is the waste generation. The first step to implement measures to implement a waste management plan at a University is to know the composition, the amount and the distribution of the waste generated in its facilities. As the waste composition and generation depend among other things on the climate, these variables should be analyzed over one year. This research work estimates the waste generation and composition of a Spanish University, the Universitat Jaume I, during a school year. To achieve this challenge, all the waste streams generated at the University have been identified and quantified emphasizing on those which are not controlled. Furthermore, several statistical analyses have been carried out to know if the season of the year or the day of the week affect waste generation and composition. All this information will allow the University authorities to propose a set of minimization measures to enhance the current management.

Key words: Waste; composition; generation; management; University.

1. Introduction

The huge amount of waste produced, and consequently the great difficulty to eliminate it is still a problem of the developed societies. This problem is embedded in the economic system of production and consumption of the current society which increasingly generates a great amount of waste. This increase in waste production leads to a risk in human health and in the environment (Tejedor, 2011). To contribute to a correct waste management, the design and implementation of new tools are needed that allow the users to reduce the amount of waste generated and improving waste management. Moreover, the amount and composition of the waste generated can depend on several factors such as the time of the year, the climate, the development degree, the standard of living, the eating habits, etc. (Aranda Usón et al. 2012; Mendoza & Izquierdo 2007; Tchobanoglous et al. 1993).

Nowadays, Universities can be considered small towns as they have several campuses and buildings where the consumption of energy, water, paper and other resources such as restaurant, cleaning, reprography and photocopy services are important. All these issues have an influence on the daily activity of many people and enterprises. Furthermore, they generate some direct and indirect impacts on the environment. For this reason, Universities must accept their institutional responsibility (Capdevila, 1999). In any case, these impacts could be minimized applying appropriate technical and organisational measures (Alshuwaikhat & Abubakar 2008).

As the rest of institutions involved in the knowledge transmission, from the research as well as the teaching point of view, Universities cannot ignore the environmental challenge. For this reason, many Universities have developed studies to implement in their facilities measures to reduce the impact generated. One of these measures is the correct waste management.

The design of University waste management systems (UWMS) of the industrialised countries started 20 years ago. There are voluntary as well as institutional programmes (Armijo de Vega et al. 2003). Some of the initiatives implemented to recycle and reduce waste have been very successful. In U.S.A. the recycling programmes are one of the most popular measures, where the 80% of the Schools and Universities have institutional programmes (Allen, 1999). These programmes are based on previous studies about waste characterization because the knowledge of waste composition and the market of the recyclable materials make them more successful than if they are copied from other places, where the conditions are different (Armijo de Vega et al. 2008).

The international published studies are varied. In Mexico, The Universidad Autónoma de Baja California (UABC) published a report in 2003 where the authors described the necessary measures to implement a waste management plan, highlighting the necessity of cooperation of all the University sectors to achieve an efficient waste management

(Armijo de Vega et al. 2003). In 2008, pursuing this policy, they obtained a waste generation rate of the UABC of 45.60 g/user/day. Most of the waste was recyclable or potentially recyclable waste (Armijo de Vega et al. 2008). The research centre “Centro de Investigación y de Estudios Avanzados de Mérida” (CINVESTAV-Mérida) of the National Polytechnic Institute implemented a programme to minimize and recycle the waste generated at the University. This fact allowed the University to reduce in 2003 the amount of waste sent to a landfill in a 67% as well as to yield large savings to the institution mainly through the reduction of waste transport costs to the final disposal places (Maldonado 2006). In Mexico D.F., the Universidad Iberoamericana (IBERO) quantified and characterized its waste in the years 2008-2009 with the aim to present proposals to improve waste management. In this way, they obtained a maximum generation rate of 330 g/user./day. They also noted that 52% of the waste generated is suitable for composting, 27% is recyclable material and 21% should be sent to a landfill (Ruiz Morales 2012).

Furthermore in Venezuela, the Universidad Simón Bolívar (USB) in 2007 proposed a recycling program to allow waste reduction. Moreover, they implemented a pilot phase where some students collected paper and cardboard separately and afterwards they sold it with the aim of increasing the number of students involved and sensitized (Pellegrini Blanco & Reyes Gil, 2009).

The University of Massey (New Zealand) described how to implement a “Zero Waste” programme in the campus (Mason et al. 2003). Subsequently, they studied the waste source separation carried out in the campus and they obtained a waste generation rate of 42 g/user/day (Mason et al. 2004).

In Prince George campus of the British Columbia University (NBCU) in Canada, during the school year 2007-2008, a study about their waste generation and composition was carried out. The biggest waste fraction was the paper-cardboard fraction, followed by plastics and organic waste. Moreover, they conclude that more of 70% of the waste could have been recycled or composted and that the University waste generation rate was 59.20 g/user/day (Smyth et al. 2010).

The University of Tabriz (Iran), during the school year 2009-2010 studied the quantity and composition of the solid waste generated as a previous step to implement the management strategies. From this study, they obtained a daily generation rate of 131.50 g/user/day. The organic waste represented the biggest proportion (almost 45.30%) followed by plastics and paper-cardboard (Taghizadeh et al. 2012).

In Nigeria, the University of Covernant carried out a study in the same way. They obtained a generation rate of 60.50 g/user/day and they observed that the biggest fraction was the food waste, followed by the polyethylene bags and the plastic bottles (Okeniyi & Anwan 2012).

Spanish Universities have paid more attention to the impact of the waste on the environment. The Universidad Autónoma of Barcelona and Madrid (UAB and UAM respectively) were pioneers in proposing measures to reduce this impact (Pujol & Espinet 2002). The Universidad Politécnica de Cataluña (UPC) was also pioneer in designing a UWMS. They developed research studies related to the waste management at the University (Tejedor 2011). The different Spanish research in this field, at the moment, is based on surveys, interviews and/or statistical data, but none of them shows results about the waste characterization.

As mentioned before, the first step to implement measures to allow establishing an efficient UWMS is to know the composition, the amount and the distribution of the waste generated. The lack of studies of characterization of the waste generated at the Universities leaves patent the need to research in this field.

In this work, Universitat Jaume I waste generation and composition has been estimated during a school year. For this reason, all the waste streams generated at the University have been identified and quantified emphasizing on those which are not controlled. Furthermore, several statistical analyses have been carried out to know if the season of the year or the day of the week, affect waste generation and composition. All this information will allow the University authorities to propose a set of minimization measures to enhance the current UWMS.

2. Methodology

The Jaume I University (UJI) is located in Castellón de la Plana, Spain. In 2013, the University enrolled 16,600 students, 1,192 professors and 597 people working in services and administration activities (PSA). The University campus has several buildings distributed in three main zones: three Faculties and one engineering School, sports facilities, a library, the Rectorate building and the laboratories building. The three Faculties, the engineering School and the Rectorate building have a university canteen. There is also a commercial zone (Ágora), which is opened to the entire town that has not been taken into account in this study (Figure 1)

The University is opened all the year (from Monday to Saturday) except for the month of August, one week on Christmas holidays and another one on Easter holidays. The classes of the first period usually start over September10th and finish on 23 December. From January 8th to 28th students have an examination period. The second teaching period runs from January 29th to May 30th. From July 1st to July 30th there is another examination period. During the examination periods there are no classes and students go to the University to prepare their examinations at the library and study areas. In July, canteens are only opened in the morning.

The research work was carried out during the school year 2013-2014. The school year was divided into two periods which coincides with both teaching periods. The first of them covered autumn and winter seasons and the second one covered spring and summer seasons.

The study was divided in four stages: Identification of waste generation sources, estimation of the waste generation, estimation of the waste composition and a final step of analysis and results.

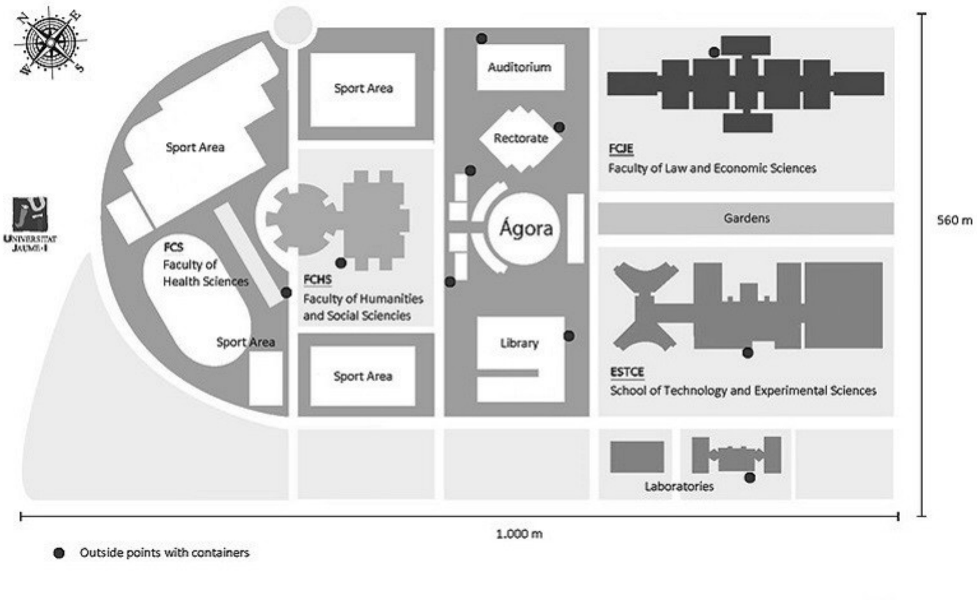

Figure 1. Jaume I University map and sampling points.

2.1 Identification of the waste generation sources.

To know the current situation of the UWMS at UJI, all the available written information was gathered and some interviews with the cleaning service and waste managers. In the UJI there is an Office of Labour Risk Prevention and Environmental Management (OPEM) that is responsible for the management of all kind of waste. The OPEM controls and monitors the hazardous waste (such as waste of chemical products, waste of biologic products, polluted glass and plastics, batteries, electrical and electronic waste, etc.) and non-hazardous waste collected selectively (paper-cardboard, light-packaging, glass and used clothes). Regarding waste management in the campus, there is a clear difference between hazardous and non-hazardous waste. While the hazardous waste must be rigorously controlled (source separation, counting of generated amounts, contracting specialised collection companies, etc.), non-hazardous waste (similar to municipal solid waste by the current regulations) only require to be deposited into bins. Therefore, afterwards they will be collected by the municipal services.

However, based on the UWMS at UJI, the non-hazardous waste is separated in source in four fractions: paper-cardboard, light-packaging, glass and mixed waste (MW). To collect the first three fractions, the University has a net of selective bins, inside and outside the buildings. The MW is made up of waste generated at the canteens and by the cleaning services of the classrooms, offices and laboratories.

Light-packaging, paper-cardboard and glass fractions are already counted because UJI receives money depending on the amounts of waste collected while it is not the case of the MW.

In this first stage of the methodology all the disposal points of the MW at UJI were identified. For this purpose, all the buildings of the campus were checked to find these points.

2.2 Estimation of the waste generation.

To determine the total amounts of waste generated in the campus it is only necessary to estimate the generation of the MW as the others fractions are already counted as mentioned before. Therefore, a work plan to minimize the necessary resources (time and people) was designed. The results obtained have an acceptable level of error.

Due to there was no availability to weigh all the MW daily, the degree of filling of the bins was monitored. Two monitoring processes were proposed during the school year, one in each teaching period.

In order to obtain representative results, the minimum number of days to be monitored should be calculated. The minimum sample size (or number of monitoring days) was calculated using equation 1 for continuous data (Bartlett et al. 2001):

$$n_0 = \left(\frac{t \cdot S}{e \cdot \acute{X}} \right)^2 \quad (1)$$

Where n_0 is the minimum number of monitoring days, t is the percentile that depends on the confidence level, S is the standard deviation, $\overline{X}$ is the arithmetic mean of the generation and e is the acceptable level of error for the mean. The confidence level was 90% (α=0.1), therefore t=1.28. The acceptable level of error was fixed as 10%.

If n_0 was greater than 5% of the population size (N), a corrected equation of the sample size should be used (Equation 2):

$$n = \frac{n_0}{1 + \frac{n_0}{N}} \quad (2)$$

As there were no data available about the mean and S, a pilot study was carried out. In this study the bins were monitored during an entire working week (5 days), getting a mean of 831.43 kg of MW per day and a S of 206.94 kg of MW per day. Attending to equation 1, the sample size obtained was at least of 11 monitoring days. Taking into account that the N is 108 working days, length of the first teaching period in which the pilot study was carried out, the value of n_0 is the 10.19% of it. Consequently, it was necessary to use equation 2, getting a value of n = 11. For the second teaching period, with a length of 107 working days, the same procedure was used and the result was a monitoring period of 11 days.

Once the sample size was calculates, the monitoring process was designed. This process was carried out during two and a half weeks in the month of October (15 days), for the first teaching period, and during one week in April and two weeks in May (17 days) for the second teaching period. At 21:30 h, when the cleaning service is over, the number of bags deposited in all the points was counted. As the cleaning and canteen staff use several colours bags, it allowed to differentiate and to quantify the MW separately depending on its source. For that reason, data about canteen waste generation and cleaning service waste generation were obtained.

The first day of each period, all the bags were weighed and the average weight per bag was determined. Consequently, the following days from the number of bags collected in each point the amount of MW deposited per point was obtained.

2.3 Estimation of the waste composition

As in the generation case, to determine the waste composition it is only necessary to characterize the MW. A work plan was designed with the same aim that the one mentioned before. In both teaching periods, the waste composition of the cleaning service and the canteen waste was determined separately.

In the first place, the minimum number of samples to obtain a representative composition in both periods must be defined. For this reason, equation 1 was used again (t = 1.28 y e = 10%). As there was no initial data available about waste composition (mean and S per component), a preliminary pilot study of characterization of the canteen and cleaning service waste was carried out (three samples were characterized). Subsequently, equation 1 was applied to the two biggest fractions of each waste stream (cleaning service and canteen). Table 1 shows the results obtained in this case. At least 3 sampling days of each stream are required to get representative results of waste composition.

Table 1: Biggest fractions and results of the sample size (n_0).

	Main components	Mean (%)	Standard Deviation (%)	n_0
Canteen waste	**Organic Matter**	**61.02**	**8.03**	**3**
	Plastics	**9.67**	**1.28**	
Cleaning waste	**Dirty paper**	**43.95**	**5.92**	**3**
	Clean paper	**12.73**	**1.14**	

Finally, seven waste samples were collected in each period to be characterized, three of them from the canteen and four of them from the cleaning. All of them were analyzed at the laboratory. In the characterization process, 15 categories of waste were identified: plastics (PET, HDPE, LDPE, PP and PS), ferrous metals, non ferrous metals, clean and dirty paper, clean and dirty cardboard, tetra-brick, glass, organic matter, sanitary cellulose (diapers, sanitary towels, tampons, etc.), rubber and leather, toxic and hazardous waste and inert waste.

2.4 Results and statistical analysis of the data.

The waste weights obtained in the monitoring process of the daily generation were registered in a database. The data were separated depending on the period and the day of the week. From this database the central tendency and the variability of the distribution were calculated. Moreover, other statistical evidences were calculated: counterfactual scenario (Student t-test for independent samples), with the aim of detecting if there is any difference for waste generation in both periods and one-way ANOVA with repeated measures to know if the factor “day of the week” affects the generation. From the daily generation data and the number of users of the University, the generation rate (GR) was calculated.

The data obtained in the characterization process were registered in a database, separating them depending on the period and the type of stream. The percentage in weight of each wet fraction related to the total weight was calculated. From these data, once again, the central tendency and the variability of each waste fraction and stream were calculated. In order to detect if there is any difference in the composition between both periods, the Wilcoxon Rank-Sum test was performed for each component and stream.

All the statistical analysis were calculated using the R free open-source software.

3. Results and discussion

3.1 Identification of the waste generating sources

From the information provided by OPEM and after a fieldwork at the campus, all the collection points of the University were identified and located. There are collection points inside the buildings as well as outside the buildings. Inside the buildings there are waste baskets for the MW and paper-cardboard and light-packaging bins in the hallways. Inside the professors offices there are wastepaper baskets and a special little bin for the paper. In the classrooms there are waste baskets. In every building hall there are containers for used batteries, electrical and electronic wastes and packaging of ink and toner.

Outside the buildings, there are 10 points with containers for paper-cardboard, light-packaging, glass and MW (figure 1). These bins, of 1,100-3,200 liters, contain the bags coming from the cleaning of the University facilities (classrooms, offices, waiting rooms, toilettes, hallways, sport facilities, laboratories-workshops and emptying of waste-paper bins) and the waste of the canteens.

Furthermore, there is a transfer station for the hazardous waste which is collected separately in all the laboratories.

3.2 Waste generation at UJI

The OPEM, since 2003, develops an annual report where the annual generation rate collected selectively is calculated. This rate represents the amount of waste collected selectively by the OPEM (hazardous and non-hazardous waste) from the total University community (students, professors and PSA) per year.

During 2013, 9.44 kg per user of this type of waste was collected. Taking into account that the school year has 215 working days (from Monday to Friday), the selective waste generation rate was 43.92 g/user/working day. However, this indicator does not reflect the total generation rate, as the MW is missing.

Regarding the MW, once the monitoring of the outdoor bins in both teaching periods was finished, data analysis and results were carried out. In the first period, an average amount of 474.85 kg of canteen waste and 306.63 kg of cleaning waste were generated per working day. The total amount of MW generated was definitively of 781.06 kg/working day with a standard deviation of 111.39 kg/working day. The average generation on Saturday was smaller, 100.89 kg with 9.19 kg/day of standard deviation. This is due to a smaller inflow of persons on Saturdays as there is no academic activity. The average weight per bag was 7.29 kg for the canteen waste and 4.29 for the cleaning waste with standard deviations of 3.23 and 1.89 respectively. Finally, the generation rate of MW for this period was 43.90 g/user/working day.

In the second teaching period, the average waste generation per working day was 461.57 kg for the canteen waste and 375.06 kg for the cleaning waste. The total amount of waste was 836.63 kg of MW and a standard deviation of 75.43 kg per working day. On Saturdays the average generation was 256.02 kg/day with a standard deviation of

129.66 kg/day. The average weight per bag was 7.24 kg/bag in the case of the canteen waste and 4.72 kg/bag in the case of the cleaning waste, with standard deviations of 2.66 and 2.06 kg/bag respectively. In this second period the generation rate of the MW was 47.02 g/user/working day.

In both periods, the four canteens were the grater generation points where there were canteen wastes as well as cleaning wastes. In the rest of points (six in total) there are only cleaning wastes. The average weight in both periods is very similar which underlines that following up the bins filling through the average weight of the bags is correct.

To determine if there was a significant difference between the average waste generation per working day in both periods a contrast of hypothesis was carried out. This test allows to know if the differences between two samples are real or what it is the same, the differences are not a chance occurrence and therefore they belong to different populations. It also allows to know the opposite effect, if the differences are so small that they are a chance occurrence and therefore both samples belong to same population. In the first place, the Shapiro-Wilk Test was used to verify the normality of the population. The results showed that the populations in both periods fitted a normal distribution. Afterwards, a contrast on the variance coefficients (F-Snedecor Test) allowed knowing that both samples have the same variances. Finally, after applying a t-student Test with a 95% confidence level (α=0.05), the results showed a statistical value t= -1.5525 and an associate p=0.1326, greater than α. Therefore, it can be assumed that there are no differences in the generation of the MW per working day between both teaching periods. Consequently, it can be said that the daily average per working day is 811.03 kg with a standard deviation of 96.18 kg and the generation rate is 45.58 g/user/working day.

To conclude, if the generation rate of the MW and the generation rate of the waste collected selectively are added, the total generation rate is estimated in 89.50 g/user/working day. Table 2 shows the waste generation rates calculated in other Universities, being the generation rate of the UJI the third highest.

Table 2. Waste generation rates in different Universities.

University	Waste Generation Rate (g/user/working day)
Universidad Iberoamericana*(Ruiz Morales 2012)	330.00
University of Tabriz (Taghizadeh et al. 2012)	131.50
Universidad Jaume I	89.50
Covenant University (Okeniyi & Anwan 2012)	60.50
University of Northern British Columbia (Smyth et al. 2010)	59.20
Universidad Autónoma de Baja California (Armijo de Vega et al. 2008)	45.60
Massey University (Mason et al. 2004)	42.00

* Typical maximum generationrate

It has been also verified that the generation rate of the MW and the generation rate of the waste collected selectively are similar. This fact shows the importance of the MW stream related to the total waste generated at UJI. For that reason, it would be interesting to act on this stream to improve the waste management in this University.

The sampling also allowed studying the variation in the generation during the week. From the data extracted in both campaigns, the daily average was calculated (figure 2). To determine if there is a significant difference in the MW generation rate during the 6 days of the week analyzed, an ANOVA variance analysis of a factor with repeated averages was carried out. This method allows studying if the factor “day of the week” affects the daily average generation, with 95% level of confidence (α=0,05). The results achieved were F=32.94 and an associate p less than 0.005 which imply that there are differences in the average generation at least in one day so consequently the factor “day of the week” affects the generation.

A contrast of hypothesis has showed that the daily average generation of the MW is the same from Monday to Friday and it is different on Saturdays because when this day is compared with the others the associate *p* value in less than 0.001 in all the cases. Moreover, it was later verified with Barlett test that the variances are homogeneous and the populations follow a normal distribution.

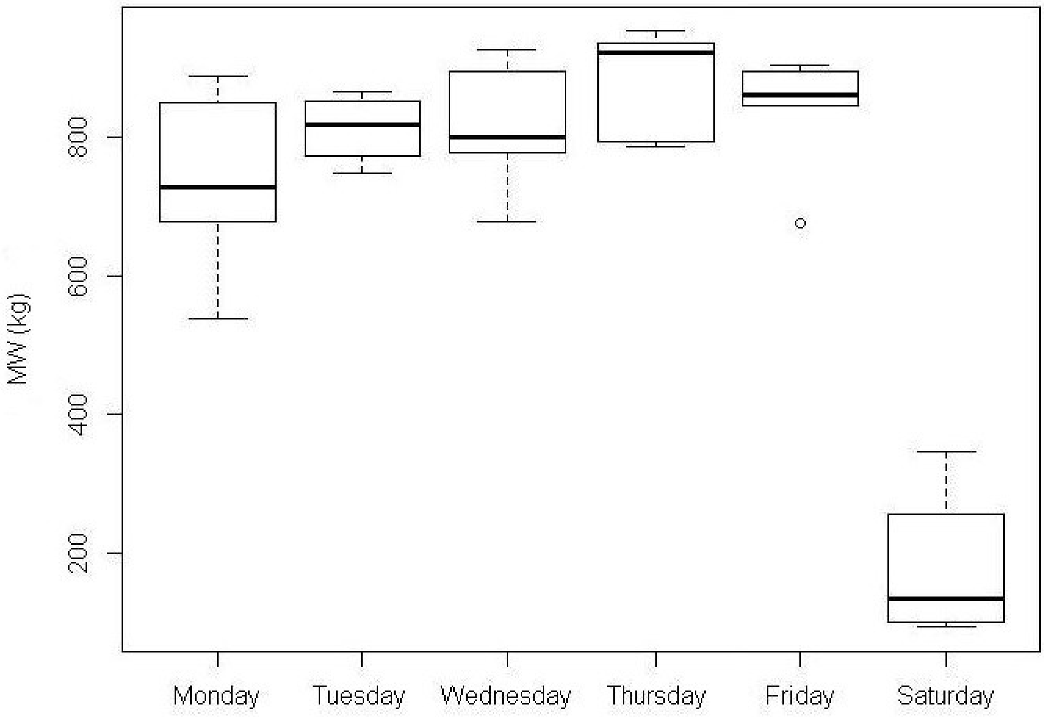

Figure 2. Daily generation rate of MW at UJI

3.3 Composition of the MW at UJI

The waste composition was determined from the OPEM information and from the MW characterizations carried out at the laboratory.

The MW was characterized in both teaching periods. The average weight of the canteen samples and the cleaning samples were 29.60 kg/sample and 10.60 kg/sample respectively. A final amount of 177.63 kg of canteen waste was characterized (93.92 in the first period and 83.72 kg in the second period). In the case of the cleaning waste, 84.89 kg of waste were characterized (36.36 kg in the first period and 48.53 kg in the second period)

Regarding the canteen wastes, the greatest fraction was the organic matter in both periods, with an average value of 61.03% in wet weight in the first period and 72.33% in the second period (table 3). The reason is that the food wastes are mainly generated at canteens. The second fraction generated is the dirty paper (13.99% and 14.22% for both periods respectively) that comes from tablecloths and napkins. The percentage of glass is smaller than the percentage of plastics and metals as in the canteens plastic packaging and beverage cans are most often used than glass bottles. Finally, hazardous as well as inert wastes represent the smallest fraction and they are collected separately.

Table 3. Average composition of the wet MW from canteens at UJI.

	First teaching period (%)		**Second teaching period (%)**		**Annual (%)**	
	Average	**St. Deviation**	**Average**	**St. Deviation**	**Average**	**St. Deviation**
Plastic	11.61	1.30	10.08	1.51	10.84	1.51
Metals	3.69	1.12	1.57	0.31	2.63	1.38
Clean paper	0.94	0.34	0.20	0.35	0.57	0.51
Dirty paper	13.99	5.44	14.22	1.00	14.11	3.50
Tetra-brick	0.77	0.73	0.08	0.08	0.43	0.60
Sanitary Cellulose	0.06	0.10	0.03	0.06	0.05	0.07
Rub and leather	0.14	0.10	0.04	0.05	0.09	0.09
Hazardous waste	0.07	0.06	0.00	0.00	0.04	0.06
Inert	0.00	0.00	0.00	0.00	0.00	0.00
Organic Matter	61.03	8.03	72.33	2.71	66.68	8.19
Clean Cardboard	2.90	3.80	0.47	0.62	1.68	2.78
Dirty Cardboard	1.70	2.11	0.68	0.91	1.19	1.55
Glass	3.10	2.74	0.30	0.51	1.70	2.34

In the case of the cleaning wastes, in both periods the greatest fraction was the dirty paper 48.36% in wet weight in the first period and 36.60% in the second period (Table 4). These elevated quantities are due to the use of paper to dry hands at the toilettes. In the first teaching period, the second biggest fraction of waste collected was plastic fraction (14.79%), followed by clean paper (11.73%). Nevertheless, in the second teaching period the organic matter fraction was the second greatest fraction (23.19%). The reason is that in this season, spring-summer, University users enjoy the green areas during their free and lunch time and the wastes generated are collected by the cleaning staff. As in the previous case, the smallest fractions are the hazardous and inert wastes.

Table 4. Average composition of the wet MW from cleaning wastes at UJI

	First teaching period (%)		**Second teaching period (%)**		**Annual (%)**	
	Average	**St. Deviation**	**Average**	**Average**	**St. Deviation**	**Average**
Plastic	14.79	5.52	14.49	4.29	14.64	4.58
Metals	4.44	1.07	6.71	3.93	5.57	2.93
Clean paper	11.73	3.05	6.10	8.30	8.92	6.53
Dirty paper	48.36	13.76	36.60	11.99	42.48	13.50
Tetra-brick	2.09	1.67	1.60	0.81	1.84	1.24
Sanitary Cellulose	0.44	0.10	0.62	0.33	0.53	0.25
Rub and leather	0.61	0.26	1.21	2.00	0.91	1.36
Hazardous waste	0.28	0.12	1.50	2.33	0.89	1.66
Inert	0.17	0.34	0.31	0.36	0.24	0.33
Organic Matter	10.98	3.82	23.19	11.17	17.08	10.11
Clean Cardboard	3.52	2.54	3.75	3.68	3.64	2.93
Dirty Cardboard	0.54	0.45	1.08	0.81	0.81	0.67
Glass	2.03	2.35	2.86	3.58	2.44	2.84

Table 3 and table 4 show that in both streams there are variations between periods in some fractions while other fractions remain constant. To verify this is not a chance occurrence, a contrast of hypothesis was considered as in the generation study. In this case, due to the number of data per sample is very small, it cannot be assumed normality. Consequently instead of using a parametric test as t-Student test a non parametric test was used although it is less robust. Therefore, to detect if there are differences in the waste composition in both periods, the Wilcoxon Rank-Sum Test was used for each component and stream (canteen and cleaning) with 95% of confidence level (α=0.05). The contrast statistical data and their associated *p* values are shown in table 5.

Table 5. Results of the Wilcoxon Rank-Sum Test for each fraction and waste stream.

	Canteen		**Cleaning**	
	W	**p-value**	**W**	**p-value**
Plastic	7.0	0.40	9.0	0.89
Metals	9.0	0.10	4.0	0.34
Clean paper	8.0	0.18	12.0	0.34
Dirty paper	4.0	1.00	10.0	0.69
Tetrabrik	8.0	0.20	10.0	0.69
Sanitary Cellulose	5.0	1.00	4.0	0.34
Rub and leather	8.0	0.20	11.0	0.49
Hazardous waste	6.5	0.50	5.0	0.49
Inert	-	-	7.0	0.87
Organic Matter	0.0	0.10	1.0	0.06
Clean Cardboard	8.0	0.20	8.0	1.00
Dirty Cardboard	6.0	0.70	5.0	0.49
Glass	9.0	0.08	7.0	0.88

All the associated p values of each fraction are greater than α. Consequently, it can be assumed that there is no difference in the composition between periods of both MW streams analyzed. For that reason, both periods can be joined and an annual average composition can be calculated for each stream. The average annual composition of the waste is shown in table 3 and table 4.

In the canteen stream, the selective fractions (paper-cardboard, light-packaging and glass) represent 33.15% of the composition. If these wastes would have been deposited in the selective collection bins, 155.93 kg of MW generated each working day would be reduced in these facilities, which means 33.53 t per year.

Additionally, if plastics and clean paper from the cleaning waste were deposited correctly, it would mean a daily reduction of 80.25 kg (23.56%) of the MW generated in this stream with a total annual of 17.25 t. Moreover, changing the hands drying method by other method that doesn't use paper, 144.7 kg of waste would be reduced daily (31.11 t per year).

Figure 3 shows the global composition of the MW at UJI. It has been taken into account that from the total MW generated annually a percentage of 58% in weight corresponds to canteen and 42% to cleaning service. This figure also shows that a percentage of 45.83% in weight of the MW corresponds to organic matter coming mainly from canteen, followed by dirty paper (36.03%) used as hand drying method from cleaning services and finally followed by plastics (12.44%). The minority fraction is formed by the inert wastes.

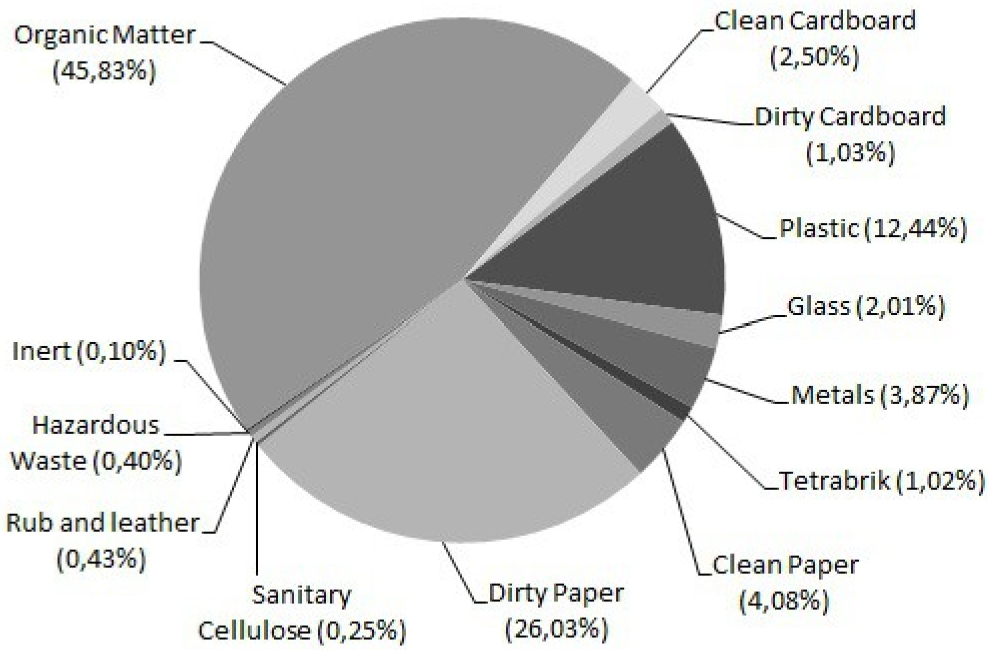

Figure 3. Global composition of the MW at UJI.

Overall, if all the material that are collected selectively at UJI (plastics, paper, cardboard, metals, glass and tetra-brick) would be deposited in their respective bins, the MW would be reduced in 429.76 kg (52.99%) per working day, in other words, it would be reduced in 92.39 t per year.

Finally, if the results achieved from experiments are joined to the OPEM data, the final waste composition at UJI, depending on the collected waste, is shown in figure 4.

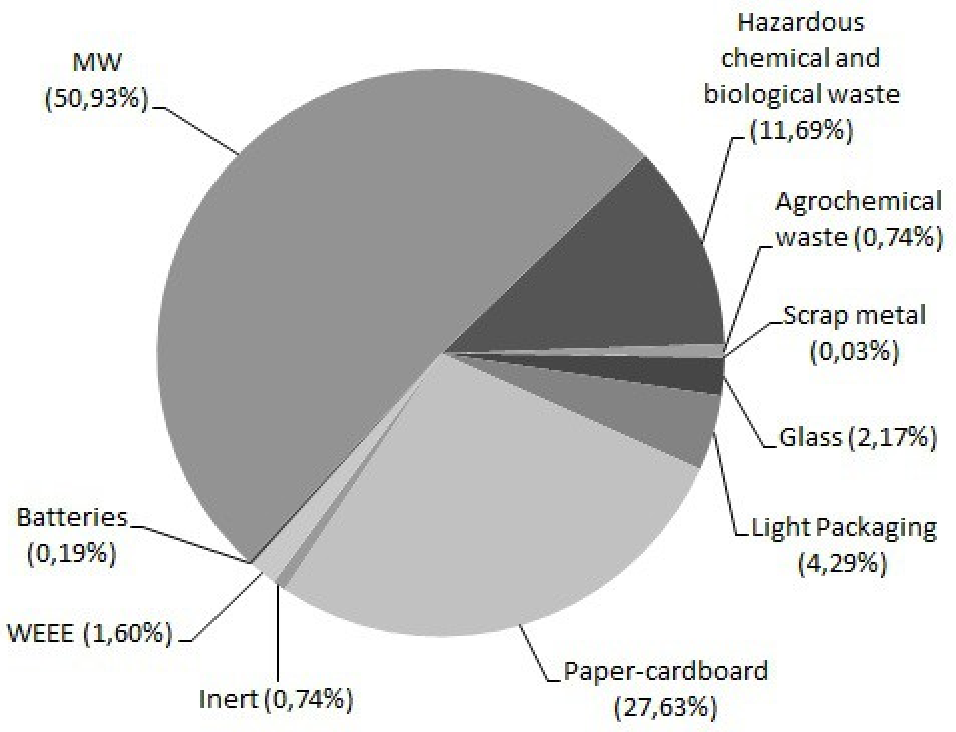

Figure 4. Global waste composition at UJI.

Figure 4 shows that the MW represents the 50.93% of the waste generated at UJI. Within this fraction, the organic matter is the greatest component, representing the 23.34% of the total waste collected. From the waste collected separately, paper-cardboard fraction represents the 27.63% followed by the hazardous chemical and biological wastes (11.69%). Both types of wastes come from the research and teaching activities carried out at this University. Scrap metal and batteries collected selectively are the minor fractions.

If these results are compared to other studies results the greatest fractions were also paper-cardboard and organic matter wastes (Taghizadeh et al. 2012; Smyth et al. 2010).

4. Conclusions.

This study presents a methodology to determine the waste generation and composition at a University and the appropriate statistical tools to establish the existence or not of the waste generation or composition variation over one school year. The results achieved are the first step to improve any UWMS.

The study analyses the particular case of the waste streams generated at Universitat Jaume I which have been identified and quantified. The hazardous waste stream and the wastes collected selectively were already quantified. That was not the case of the MW stream.

This study allowed determining that the MW generation does not vary between the two teaching periods analyzed being the daily average generation 811.03 kg of waste per working day. Moreover, it has been verified if the day of the week affects the MW generation. The results show that this generation rate is different only on Saturdays.

The MW generation rate is 45.58 g/user/working day. This value must be added to the generation rate of the wastes collected selectively, 43.92 g/user/working day. The total generation rate is consequently 89.50 g/user/working day. This value is one of the biggest University generation rates if it is compared to other values of other Universities.

Determining the composition of the canteen and cleaning waste streams allowed to know better the MW generated at UJI. The organic matter was the greatest fraction in the first case and the dirty paper was the biggest fraction in the second case. The statistical analysis allowed verifying that there were no differences in the waste composition in both periods.

This research work has permitted to know the generation and composition of the MW left daily in ten collection points of the UJI. This fraction represents the 50.93% of the total waste generated and currently it is not controlled by the OPEM. Therefore, the information achieved in this work is essential to design improvement measures of the UWMS that increase on the one hand the selective collection and on the other hand minimize the waste generated. Consequently, the adopted measures will fit to the University reality. For example, some measures are needed to extract plastics, paper, cardboard, metals, glass and tetra-brick from the MW stream. Those materials are currently collected selectively but due to different reasons they are deposited in the MW bin. If users would deposit this waste correctly, they could be reduced in 92.39 t per year the MW generation.

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