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Urban Solid Waste Characterization of the Misiones Metropolitan Area

Caracterización de Residuos Sólidos Urbanos del Área Metropolitana de Misiones

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Abstract

This paper reports the behaviour of solid urban waste generation in the Metropolitan Area of Misiones, during a period of seven days. The waste analysed came from collection routes by household sampling points determined according to the land use and socioeconomic level of the population in the study area. The methodology consisted of visualising the sample universe, selecting the household waste collection routes and then classifying and analysing their composition according to ASTM D5231-92 (2016). This strategy was considered valid, given that the habits and customs of the population are closely related to the socioeconomic levels that directly affect consumption and consequently the quality of waste. Organic matter (51.80%) was the most representative, followed by materials with recycling potential, such as plastic (13.90%), glass (7.90%), paper and cardboard (7.80%), metals/aluminium (2.20%) and tetrabrik (2.60%). The quality of MSW was not uniform between cities, with Garupá (61.50%) being the city that generated the most organic waste, followed by Posadas (57.50%) and ending with Candelaria (29.00%) with a marked decrease. As a limitation of the method, it was determined that the results are representative of each city and of the winter season.

Keywords: Municipal Solid Waste (MSW); Generation; Land Use: Socioeconomic Level; Composition.

Resumen

Este trabajo reporta el comportamiento en la generación de residuos sólidos urbanos del Área Metropolitana de Misiones, durante un periodo de siete días. Los residuos analizados provinieron de rutas de recolección por puntos de muestreo domiciliario determinados en función al uso de suelo y nivel socioeconómico de la población del área de estudio. La metodología consistió en visualizar el universo muestral, para seleccionar las rutas de recolección de residuos domiciliarios y luego clasificarlos y analizar su composición conforme a la norma ASTM D5231-92 (2016). Se considero valida esta estrategia, dado que los hábitos y costumbres de la población están íntimamente relacionados con los niveles socioeconómicos que afectan directamente al consumo y consecuentemente a la calidad de los residuos. La materia orgánica (51,80%) fue la más representativa, seguida por los materiales con potencial de reciclado, como plástico (13,90%), vidrio (7,90%), papel y cartón (7,80%), metales/aluminio (2,20%) y tetrabrik (2,60%). La calidad de los RSU no fue uniforme entre las ciudades, siendo Garupá (61,50%) la ciudad que más residuos orgánicos género, seguida por Posadas (57,50%) terminado por Candelaria (29,00%) con una marcada disminución. Como limitación del método se determinó que los resultados son representativos de cada ciudad y de la estación invernal.

Palabras clave: Residuos Sólidos Urbanos (RSU); Generación; Uso de Suelo: Nivel Socioeconómico; Composición.

Introduction

The increase in consumption levels, driven by information and communication technologies (ICTs), leads to an increasingly accelerated obsolescence of products and with it the generation of large amounts of solid waste. Buenrostro & Bocco [1] indicate that generation begins when a consumer decides that a product becomes undesirable and/or of no use to them. This instance varies according to the individual's judgement, the customs of the society in which he/she is immersed and the availability of its resources.

The increase in solid waste is one of the major problems facing local governments. The lack of adequate waste management contributes to the problem, as most cities do not collect all of the waste generated and, of the waste collected, only a fraction is properly disposed of, with the rest ending up in unmanaged open dumps. Sabino et al. [2] have reported such a situation in Latin American and Caribbean countries.

The inadequate management of solid waste causes a deterioration of the natural landscape, manifested as contamination of soil, air and water bodies. This puts human health at risk and leads to a decrease in biodiversity due to animal mortality and contamination of socially and economically important plants, as several researchers have shown in studies on the life cycle assessment (LCA) of MSW (Barlaz et al [3]; Brogaard & Christensen [4]).

In order to address the MSW problem, different technological alternatives have been developed, which can be applied to reduce the undesirable effects of waste. However, waste treatment varies according to the needs and characteristics of cities.

The choice of technology differs considerably depending on the intended outcome. Therefore, it is of utmost importance for decision-makers to have adequate information on the generation and composition of municipal solid waste (MSW).

As per-capita waste generation and waste composition is not universal. They do not depend solely on the number of inhabitants of a population, but are affected by economic, political and social aspects, such as per capita income, culture, consumption habits, land use, environmental awareness and level of development, among others. Thus, it can be expected that the per-capita generation between a developed and a developing country differs significantly.

Studies on quantification and characterisation of municipal solid waste have mainly been carried out in large cities. This leads to a lack of information on smaller cities or communities.

In order to provide information for sustainable management of municipal solid waste, the aim of this study was to analyse the behaviour of municipal solid waste generated in a seasonal period in the Metropolitan Area of the province of Misiones, Argentina, comprising the cities of Posadas, Garua and Candelaria (AMPGC).

Materials and Methods

Materials

- 30 kg electronic balance. The balance was placed on a clean, flat, horizontal surface. The accuracy and performance of the scale was determined with a set of calibrated (i.e. reference) standard weights. According to ASTM 5231-92.

- Field records. A waste recording and characterisation sheet was developed, adapted from the list of waste components maintaining the categories of ASTM 5231-92.

Methods

In order to determine the generation and composition of MSW, different sampling methodologies can be used, either through house-to-house collection or by taking samples directly from the collection truck. In this study, it was decided to collect the samples from house to house and transport them in a vehicle to the sampling centres, one per city of the AMPGC.

Collection from the selected households in the 3 AMPGC cities took place once a day, Monday-Saturday for one week, representing the usual collection frequency.

Waste analysis was carried out over 8 days in each city because samples were taken according to the frequency of the public collection system and this service is only provided from Monday to Saturday, with Sunday samples being collected on the following Monday. Several papers report a weekly duration (Rosso & De Luca [5], Liendo [6], Giorgi [7], González et al. [8]). The sampling methodology adopted for the determination of per capita waste production (PPC) was random and doubly stratified, by land use (UDS) and socioeconomic level (NSE), taking as a hypothesis that there is a direct relationship between these factors, followed by the selection of the waste collection areas, for subsequent classification and analysis. These areas are shown in Table 1- Collection areas and are represented in Figure 1- Sampling areas of Household Waste - AMPGC.

This hypothesis was considered valid because the habits and customs of the population are closely related to the socioeconomic levels that directly affect consumption and consequently the quality of the waste.

The number of samples to be collected was determined taking into account the ASTM D-5231-92 Standard Test Method for Determination of the Composition of Unprocessed Municipal Solid [9]. This Standard determines that the number of samples required to achieve a desired level of precision is a function of the waste component(s) under consideration, or at least the most important ones, and the desired level of confidence.

It was decided to use recognised territorial references in each area to make a preliminary survey of possible sampling points, this was defined by using the single sample method for a specific period of time.

This situation meant that the samples had to be taken care of to prevent them from entering the daily collection system.

Each territorial reference person went around the area to help label each sample before it was picked up in the vehicle assigned specifically for sampling. These people fulfil community functions in the neighbourhood and/or Municipal Delegations, so they contributed significantly to the logistics of collecting and labelling each bag during the sampling.

Based on the above, the methodological scheme required the setting up of logistics and specific equipment. This was carried out by defining a pick-up truck for the collection through a pre-arranged route and with a team that, upon arrival at each sampling point, was received by the reference person for the collection of the sample and its labelling.

The collection of each sample guaranteed the identification of its sampling point by its labelling. Throughout the sampling, there were no suspensions or changes of days, the sampling was carried out as planned.

Weighing, opening and sorting: was carried out at the Public Services Operational Bases of each Municipality, considering the importance of using the same facilities and personnel provided for the provision of the public collection service.

In order to obtain the data derived from each sample regarding the dwelling or commercial premises, number of households and persons, ages and other data, surveys were applied to the sampling points. These were conducted by telephone and/or in person.

The data were systematised in spreadsheets by sampling area and by city. In addition, survey systematisation spreadsheets were supplemented by on-line uploading in each municipality.

The AMPGC MSW characterisation study was carried out in the winter of 2018, on a sampling involving 54 households, inhabited by a total of 123 people, during 7 collection days, in different areas of the three cities.

The total volume of sampled waste amounted to 407.1 kg.

Table 1: Collection areas.

AMPGC CLASSIFICATION			UDS		
			Residential Industrial	Residential Com-mercial	Residential Industrial
			RI	RC	RI
SES	High Medium High	A	[1] Villa Sarita (P) [2] La Eugenia (G)		
	Medium	M	[3] Casco Céntrico(C) [4] B° del Lago (C)	[5] Av. Uruguay (P)	
	Medium Low	MB	[6] Miguel Lanús (P) [7] Chacra 150 (P) [8] B° Madariaga (P) [9] B° Nuevo (G) [10] B° Artigas (G) [11] B° Evita (C)		
	Low	B	[12] B° Lapachitos (P) [13] Santa Clara (G) [14] B° Paso Viejo (C)		

Source: Own elaboration.

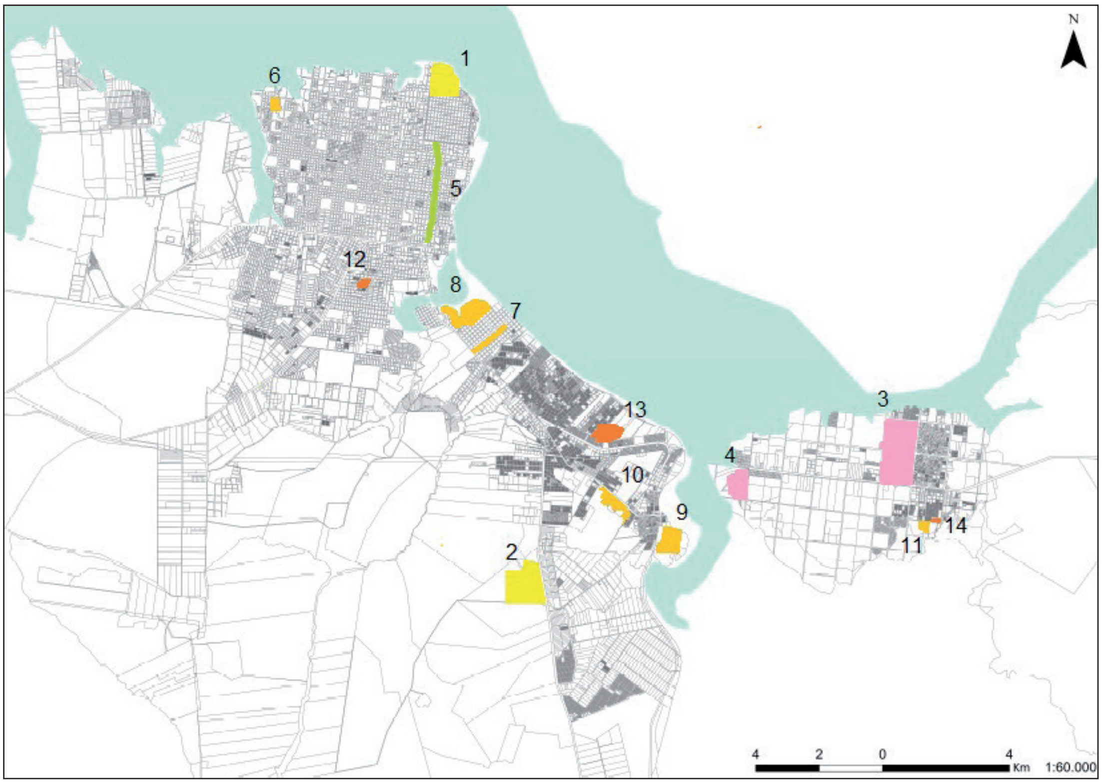

Figure 1: Household Waste Sampling Areas – AMPGC.
Source: Own elaboration.

Results and discussion

The number of sorting samples (i.e. households where waste is removed) (n) required to achieve a desired level of measurement precision is a function of the component(s) under consideration and the confidence level. The equation governing n is as follows:

$n = (t^*s/e.x)^2$ (Formula 1)

where:
t * = Student's t statistic corresponding to the desired level of confidence,
s = estimated standard deviation,
e = desired level of precision, and
x = estimated mean.

The sorting sample is chosen prior to vehicle loading.

Suggested values of s and x for the residue components are listed in Table 2. The t * values are given in Table 3 as a function of the number of samples, for the 90% and 95% confidence levels, respectively.

Table 2: Values of mean (x) and standard deviation (s) of intra-week sampling to determine MSW Component Composition.

Component	Standard deviation(s)	Mean (x)
Newsprint	0.07	0.10
Corrugated	0.06	0.14
Plastic	0.03	0.09
Yard waste	0.14	0.04
Food waste	0.03	0.10
Wood	0.06	0.06
Other organic	0.06	0.05
Ferrous	0.03	0.05
Aluminium	0.004	0.01
Glass	0.05	0.08
Other inorganic	0.03	0.06
Total:		1.00

Source: ASTM Standard D5231 - 92. Tabulated mean values and standard deviations are estimates based on field data from tests reported for MSW sampled during weekly sampling periods at various locations around the United States.

Table 3: t-Statistic (t*) Values as a Function of the Number of Samples and Confidence Interval.

N of samples	90%	95%
2	6.314	12.706
3	2.920	4.303
4	2.353	3.182
5	2.132	2.776
6	2.015	2.571
7	1.943	2.447
8	1.895	2.365
9	1.860	2.306
10	1.833	2.262
11	1.812	2.228
12	1.796	2.201
13	1.782	2.179
14	1.771	2.160
15	1.761	2.145
16	1.753	2.131
17	1.746	2.120
18	1.740	2.110
19	1.734	2.101
20	1.729	2.093
21	1.725	2.086
22	1.721	2.080
23	1.717	2.074
24	1.714	2.069
25	1.711	2.064
26	1.708	2.060
27	1.706	2.056
28	1.703	2.052
29	1.701	2.048
30	1.699	2.045
31	1.697	2.042
36	1.690	2.030
41	1.684	2.021
46	1.679	2.014
51	1.676	2.009
61	1.671	2.000
71	1.667	1.994
81	1.664	1.990
91	1.662	1.987
101	1.660	1.984
121	1.658	1.980
141	1.656	1.977
161	1.654	1.975
189	1.653	1.973
201	1.653	1.972
∞	1.645	1.960

Source: ASTM D5231 - 92.

For this study, the number of samples was determined by taking as reference parameters the statistical values of × and s of the components: food waste and plastics, as these constituents were considered to be the most representative, using ASTM D5231 - 92 as a reference.

The sample precision was determined as e = 10% and the confidence interval of 90%.

Therefore:

Food waste
s = 0.03 (Table 2),
e = 0.10 (Table 2),
x = 0,10 and
t * = 1,645 (Table 3)
applying:
$n = (t^* s / e\, x)^2$
$n = ((1{,}645\ 0{,}03) / (0{,}10\ 0{,}10))^2$
n= 24

Plastic
s = 0,03 (Table 2),
e = 0,09 (Table 2),
x = 0,10 and
t * = 1,645 (Table 3)
applying:
$n = (t^* s / e\, x)^2$
$n = ((1{,}645\ 0{,}03) / (0{,}10\ 0{,}009))^2$
n= 30

The number of samples set as sufficient for the physical determinations of the AMPGC is 30.

The number of samples selected to cover all SU and SES strata was 54.

Posadas 38 samples
Garupá 8 samples
Candelaria 8 samples

The waste was then classified into two main categories: 1) organic, 2) inorganic and the values obtained were weighed and recorded (figure 2), then classified and weighed according to the composition described in table 4.

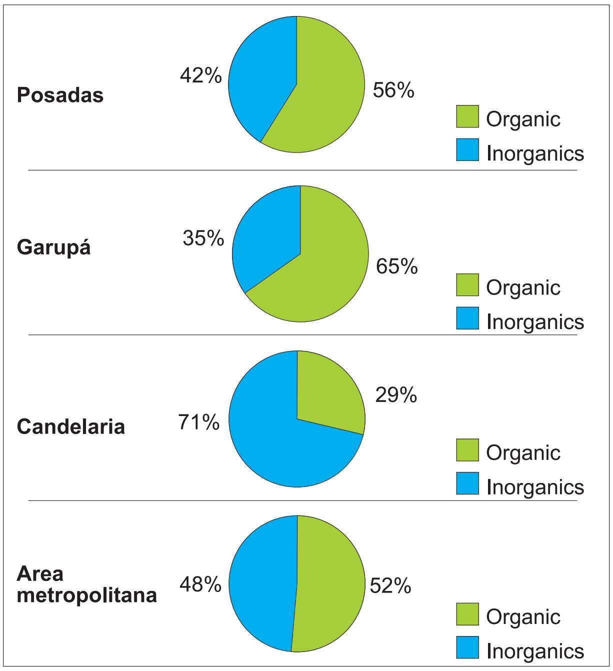

Figure 2: MSW composition - by city and AMPGC.
Source: Own elaboration.

Tabla 4: Síntesis de la composición obtenida.

	AMPGC		Posadas		Garupá		Candelaria	
Waste	**Kg**	**Composition**	**Kg**	**Composition**	**Kg**	**Composition**	**Kg**	**Composition**
Paper-Cardboard	**31,819**	**7,8%**	22,290	9,3%	2,50	3,7%	7,029	7,0%
Brick Cardboard	10,775	2,6%	5,280	2,2%	2,00	3,0%	3,495	3,5%
Steel	**4,255**	**1,0%**	1,150	0,5%	0,85	1,3%	2,255	2,3%
Aluminium	**4,901**	**1,2%**	1,440	0,6%	0,95	1,4%	2,511	2,5%
White glass	**7,557**	**1,9%**	2,050	0,9%	0,25	0,4%	5,257	5,3%
Coloured glass	**24,352**	**6,0%**	15,800	6,6%	0,40	0,6%	8,152	8,2%
Wooden look	**0,960**	**0,2%**	0,000	0,0%	0,00	0,0%	0,96	1,0%
Ceramics	**1,000**	**0,2%**	0,000	0,0%	0,00	0,0%	1,000	1,0%
Tergopol	**4,176**	**1,0%**	1,580	0,7%	1,31	2,0%	1,286	1,3%
PET	**32,773**	**8,0%**	13,360	5,6%	11,50	17,2%	7,913	7,9%
Film (LDPE)	**21,999**	**5,4%**	16,210	6,8%	0,05	0,1%	5,739	5,7%
PVC	**0,200**	**0,0%**	0,000	0,0%	0,00	0,0%	0,2	0,2%
other plastics (HDPE, PP, PS)	**2,180**	**0,5%**	0,500	0,2%	1,38	2,1%	0,3	0,3%
Textiles	**9,661**	**2,4%**	2,020	0,8%	0,41	0,6%	7,231	7,2%
Batteries	**0,000**	**0,0%**	0,000	0,0%	0,00	0,0%	0	0,0%
Fluorescent lamps	**0,000**	**0,0%**	0,000	0,0%	0,00	0,0%	0	0,0%
Bathroom (papers, nappies, wipes)	**39,788**	**9,8%**	20,300	8,5%	1,80	2,7%	17,688	17,7%
INORGANICS	**196,396**	**48,2%**	101,980	42,5%	23,40	34,9%	71,016	71,0%
Food waste	**149,448**	**36,7%**	88,32	36,8%	42,05	62,7%	19,078	19,1%
Garden waste	**15,131**	**3,7%**	9,5	4,0%	0,00	0,0%	5,631	5,6%
Wood	**1,858**	**0,5%**	0,11	0,0%	0,00	0,0%	1,748	1,7%
Other organic materials	**44,300**	**10,9%**	40,2	16,7%	1,60	2,4%	2,5	2,5%
ORGANIC	**210,737**	**51,8%**	138,13	57,5%	43,65	65,1%	28,957	29,0%
TOTAL	**407,133**	**100,0%**	240,110	100,0%	67,05	100,0%	99,973	100,0%

Source: Unidad Ejecutora de Proyectos Especiales - Municipality of Posadas.

Figure 3 shows the detail of the organic fraction of MSW from the Misiones Metropolitan Area and Figure 4 shows the detail of the inorganic fraction of MSW from the Misiones Metropolitan Area.

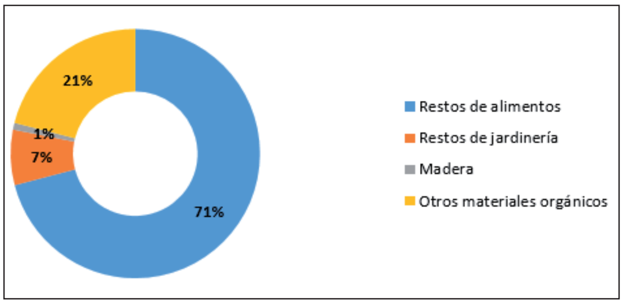

Figure 3: Detail of the inorganic fraction AMPGC.
Source: Own elaboration.

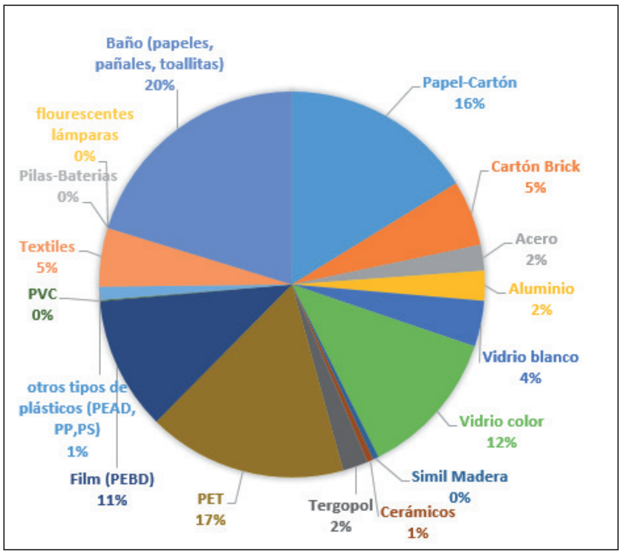

Figure 4: Metropolitan Area MSW composition, detail of the organic fraction.
Source: Own elaboration.

Conclusions

The general conclusions of the Quality Study are as follows:

It has been observed that organic matter (51.80%) was the most representative, followed by materials with potential to be recycled, such as plastics (13.90%), glass (7.90%), paper and cardboard (7.80%), metals/aluminium (2.20%) and tetrabrik (2.60%).

The main fractions that can be recycled are paper and cardboard, plastic materials and organic waste (garden waste and wood) for composting.

It has been observed that the quality of MSW is not uniform in the cities of Posadas, Garupá and Candelaria, with Garupá (61.50%) being the city that generates the most organic waste, followed by Posadas (57.50%) and ending with Candelaria (29.00%) with a marked decrease.

According to the average obtained from the commercial residential area of Av. Uruguay, compared to the residential area, there is a difference of more than 50kg in paper-cardboard type waste, where 59.8kg comes from Av. Uruguay in Posadas, compared to 7.95kg identified in the residential area. Other interesting values are those for film waste of 13.61kg in Av. Uruguay, compared to 5.50kg in residential neighbourhoods, with a similar behaviour in textile waste of 13.5kg versus 2.42kg, reversing the relationship in bathroom waste of 2kg and 9.95kg and food waste of 0.9kg and 37.45kg.

Finally, there is a difference between the extremes of SES, with a greater presence of toilet waste in the poorest households versus those with higher incomes, mainly nappies 17.52kg versus 3.9kg, in correlation with the higher birth rate in this segment in relation to the higher levels, and on the contrary, the lower ratio in organic food waste 31.25kg and 36.9kg.

As a limitation of the method, the results are representative of the winter season.

References

1. **Buenrostro O., Bocco G. (2003).** *Solid waste management in municipalities in Mexico*. Goals and perspectives - Resources, Conservation and Recycling V.39, P.251-263.
2. **Savino, A., Solórzano, G., Quispe, C., Correal, M. (2018)** *Perspectiva de Gestión de Residuos para América Latina y el Caribe* - ONU Medio Ambiente - ISBN No 978-92-807-3715-8.
3. **Barlaz, M., Starostina, V., Boldrin, A., Astrup, T., Bisinella, V. (2020)** *Application of LCA modelling in integrated waste management*. Waste Management. V. 118, P. 313-322.
4. **Brogaard, K. & Christensen, T. H. (2016)** *Life cycle assessment of capital goods in waste management system*. Waste Management. V. 56, P. 561-574.
5. **Rosso, M., De Luca, M. (2019)** *Estudio de calidad de los residuos sólidos urbanos de la provincia de Santa Cruz*. Rio Gallegos. IEASA.
6. **Liendo, I. T. (2018)** *Estudio de generación y caracterización de residuos sólidos en la provincia de Jujuy*. San Salvador de Jujuy. INTERSMETICA.
7. **Giorgi, F., Giorgi, A., Guaresti, M., Nielsen, O., Rueda Serrano, C. (2015)** *Estudio de calidad de los residuos sólidos urbanos de la Ciudad Autónoma de Buenos Aires*. Buenos Aires. IIS/FIUBA CEAMSE.
8. **González, L., Naquin, P. Méhu, J. (2015)** *Estudio de Caracterización de los Residuos Sólidos Municipales de la ciudad de Córdoba*. Córdoba. PROVADEMSE-INSAVALOR.
9. **Norma ASTM D-5231-92 (Revisada y reaprobada en el año 2016)** *Standard Test Method for Determination of the Composition of Unprocessed Municipal Solid Waste.*