

CHARACTERIZATION OF THE POLYMERIC WASTE, POST-CONSUMPTION, DISPOSED IN THE SANITARY LANDFILL OF THE MUNICIPAL OF SÃO CARLOS, SP

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SUMMARY: The objective of the present work is to present a physical characterization of the polymeric wastes conducted in the conventional collection of the municipality of São Carlos, SP. The method adopted for physical characterization was by sampling, where the number of samples involved all of the sections, with the weight of each sample obtained by quartering. Characterization was performed in the winter and another one in summer. The results that stand out are the percentage of polymeric wastes, in weight of 10,47%, composed by PET (35,96%), HDPE (26,42%), PP (16,25%), PS (7,96%), Other (7,85%), PVC (3,76%), and LDPE (1,79%). It was observed that the percentage of polymeric wastes destined to the sanitary landfill is still high, considering the existence of selective collection, and that the PET resin was considered the largest in the participation index, overcoming PEAD, traditionally the one considered the most abundant discard of household wastes.

1. INTRODUCTION

The Polymeric wastes, post-consumption, commonly known as "plastics", have been, in the last decades, increasing their participation in the bulk of urban waste, as shown in Table 1, which presents characterizations of certain cities of Brazil and the United States of America, the largest world producer of plastic resins.

Plastics possess the added inconvenience of being slow degrading material, which remain in the environment for long periods of time, compromising the life cycle of the sanitary landfills as a result of a very high volumetric occupation, due to its specific low weight. This substance is endowed with a high return potential as raw material, whether it is reused or recycled. Generally, plastics (synthetic polymer) originate from petroleum, a raw material of non-renewable natural resources, with an elevated cost always tending towards increasing price quotations, besides being an influential generating factor in the global economy.

Table 1. Physical characterization of the solid wastes of some cities, in percentile weight (Adapted of (Gomes, 1989); (COMLURB, 2002); (Zeng, Y., et all, 2005))

City	Year Publication	Plastic	Glass	Metal	Paper	Organic	Other
São Carlos (SP/BR)	1975	7,2	6,3	5,6	20,5	40,4	20,0
Rio de Janeiro (RJ/BR)	1986	9,7	3,4	3,7	38,4	38,6	6,2
Columbia (USA)	1987	7,0	4,0	6,0	41,0	7,0	35,0
São Carlos (SP/BR)	1989	8,5	1,4	5,4	21,3	56,7	6,7
EPA (USA)	1994	12,0	6,0	6,0	33,0	9,0	34,0
Columbia (USA)	1996	16,0	3,0	6,0	41,0	9,0	25,0
Rio de Janeiro (RJ/BR)	2002	17,6	2,7	1,9	18,7	55,9	4,9

Table 2 Codes and Abbreviation of identification of the synthetic polymers (ABNT (NBR – 13230, 1994))

Codes	Abbreviation	Polymer
1	PET	polyethylene terephthalate
2	HDPE	polyethylene high-density
3	PVC	polyethylene high-density
4	LDPE	polyethylene low-density
5	PP	polypropylene
6	PS	polystyrene
7	OTHER	-

The Polymeric wastes, post-consumption, become separated in rigid and film plastics. Rigid plastics are found in several food packings, soft drinks, cleaning material, personal hygiene, among others, while the film plastics are seen in supermarket bags and packings for vegetables and bakery goods.

There are some studies that display characterizations of urban waste with polymeric wastes, post-consumption, subdivided into rigid plastic and flexible plastic or film. This separation is important when verifying the recycling potential of each type of plastic. Table 2 illustrates the participation percentage, in weight, of rigid and film plastics of some Brazilian cities.

As verified by Matos (2006), the thermoplastic polymers, represent most of the polymeric wastes found in household wastes. Polymeric wastes, post-consumption, are basically composed of PET resins (polyethylene terephthalate), HDPE (polyethylene high-density), LDPE (polyethylene low-density), PVC (polyvinyl chloride), PP (polypropylene), and PS (polystyrene).

In Brazil, there are few characterizations that evaluate the percentage participation of the several thermoplastic resins (PET - HDPE - PVC - LDPE - PP - PS - Others) that are in the household waste. According to Zanin and Mancini (2004) the two characterizations accomplished in Araraquara/SP - 1995/1996 and 1997/98 and 99/2001 - and one in Botucatu/SP, shown in Table 3, are the only ones found in Brazilian literature, which include the characterization of rigid plastics found in conventional collection.

Table 3. Percentage composition, in weight, rigid and film plastics, of the collection of some Brazilian cities (Adapted of (Mancini, 1996); (Castro, 1996); (Silva, 2003); (Oliveira, et al, 1995)). * Plant of selection of São Matheus.

City	Year Publication	Plastic	
		Rigid (%)	Film (%)
Araraquara/SP	1995/1996	1,97	10,13
Salvador/BA	1995	5,07	12,03
São Paulo*/SP	1996	2,51	8,68
Natal/RN	2002	2,64	3,37

Table 4. Characterizations of rigid plastics in Brazilian cities (Adapted of (Zanin e Mancini, 2004)).

Cidade	Ano de Realization/ Publication	HDPE (%)	LDPE (%)	PVC (%)	PET (%)	PP (%)	PS (%)	OTHER (%)
Botucatu (SP)	1997/2000	20,4	4,6	2,4	33,3	6,2	33,1	
Araraquara (SP)	1995/1996	46,7	0,5	5,5	34,5	9,2	3,0	0,6
Araraquara (SP)	1997/98 e 99/2001	28,1	0,3	2,1	63,6	3,2	1,2	1,5

The codes (numbers) of the thermoplastic polymers are standardized by ABNT (NBR - 13230, 1994) and represent indicative symbols of recycling and plastic materials identification, which can be seen in Table 4

This work is justified, within the optics of academia, on account of the possibility to generate information regarding the thermoplastic polymeric solid wastes (plastic packings), more specifically, with regard to their characteristics and percentage compositions found in the household wastes (HW) of the municipality of São Carlos, SP, which are important for sanitary and social aspects. For the government the information is important in order to establish and improve public policies and for an integrated administration of solid wastes, especially for pollution prevention aspects based on reduction, re-usage and recycling of plastics. Considering the recycling aspect, the generated data can provide the amount of material that can be separated from each waste, thus enabling to verify the economic viability of the process. Another important factor is verification of the constant growth of plastic wastes post-consumption. A fact that stands out is that there are few registration records of studies that include data of the physical characterization of polymeric solid wastes - plastic packing - in Brazil, according to consulted bibliography.

The purpose of this work is to present the generating indexes of polymeric wastes, post-consumption, currently observed in the conventional collection of São Carlos, SP, including percentage weight and volume participation for: 1) rigid and film plastics; 2) types of resin of the rigid plastics.

2. MATERIALS AND METHODS

2.1 characterization of the study area

The municipality of São Carlos is located in the central area of the State of São Paulo and its area is represented in two Units of Water Resources Administration, the basin Tiête/Jacaré and the basin Mogí/Guaçu, according to Figure 1.

The geographic and statistical data that characterize the municipality of São Carlos is in Table 5.

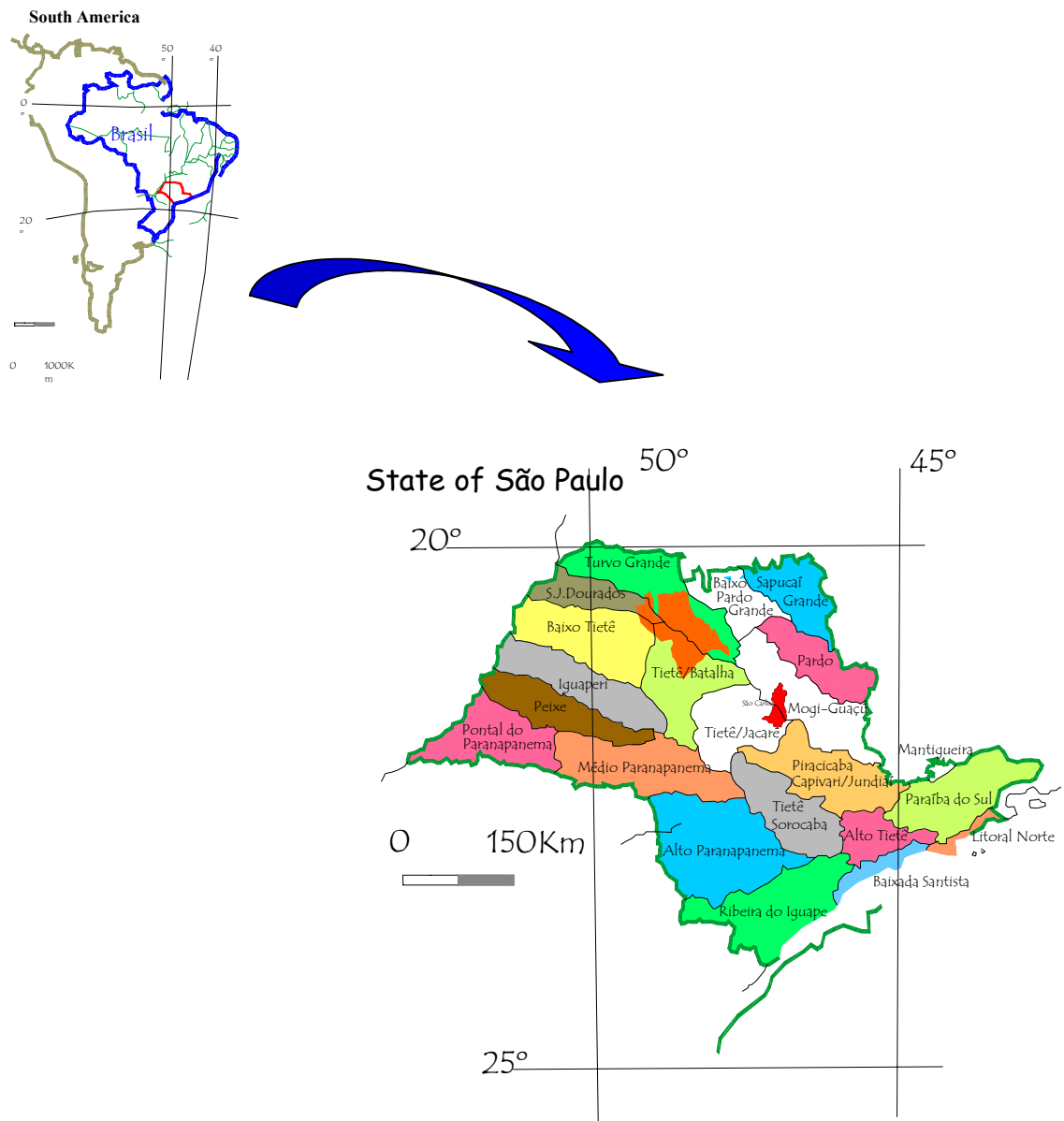


Figure 1. Location of the municipality of São Carlos in relation to South America, Brazil, São Paulo and Units of Administration of Water Resources of São Paulo (<http://www.rededasaguas.org.br>)

Table 5. Geographic and statistical data of the municipality of São Carlos/SP (Censo 2000 – IBGE, 2000).

Data	Value	Unit
Area of the territorial unit	1.140,92	Km ²
Urban area	68,45	Km ²
Rural area	1.072,46	Km ²
Total resident population	192.988	inhabitants
Resident population of the urban area	183.423	inhabitants
Resident population of the rural area	9.565	inhabitants
Annual demographic growth rate	2,40	% on year.
Number of homes of the urban area	55.356	Domicile
Number of homes of the rural area	21.489	Domicile

The population of São Carlos, SP, estimated in 01/07/2005, according to IBGE (2005), corresponds to 214.786 inhabitants.

Conventional collection is accomplished in every urban area of the municipality, as well as in the districts of Água Vermelha and Santa Eudóxia and it has a daily mean disposal of approximately 137 t of household wastes, in accordance with data from the Office of Municipal Sustainable Development of São Carlos (SMDS), SMDS (2005), which represents a per capita HW production of 0,64 kg/inhab./day of the urban population. The entire production of HW of conventional collection is destined to the sanitary landfill of São Carlos, SP.

The municipality of São Carlos, SP, possesses a selective collection system, which, according to SMDS (2004), includes 60% of the urban area, with 32.000 collection points.

2.2 characterization procedure

The method of physical characterization of the polymeric wastes, post-consumption, adopted in this work, is grounded on the methodology presented in Gomes (1989), with adaptation and updating of the procedures according to guidance by IPT/CEMPRE (2000) and ABNT (NBR - 10.007, 2004).

For more substantial signification of the sampling number, characterizing was adopted in all 15 sections of conventional collection, including, the whole urban area. For verification of the influence regarding the climatic station, a characterization was performed in winter and another in summer. According to Klee (1980 apud ZENG et al., 1986, p. 64, our translation), [...] when the sample weights decrease below approximately 91 kg, the discrepancy in the sample waste increases quickly, but above approximately 140 kg, the discrepancy increases slowly [...] a sample weight between 91 and 140 kg is recommended.

An interval of 91 to 140 kg, for the sample weight of solid wastes is also recommended by the American Society for Testing and Materials (ASTM), ASTM (2003).

In this work the approximate weight of 200 kg was adopted, obtained after quartering, according to the sample preparation procedure of what is described as follows:

The characterization procedure involved two phases: The obtainment of the representative sample of the weight of collected wastes and destined to the sanitary landfill and the characterization of the present polymeric wastes in the representative sample.

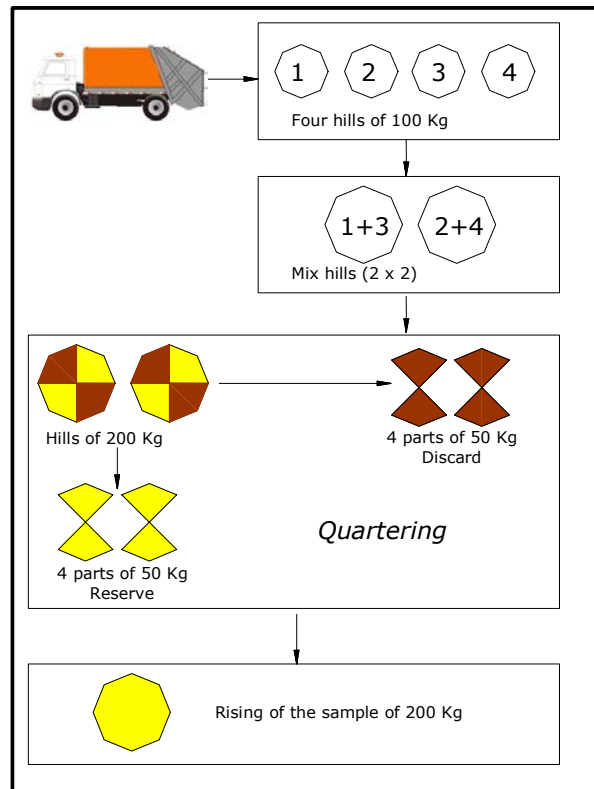


Figure 2. Diagram of preparation of the sample of HWS of the collection

2.2.1 First phase: obtaining representative sample

Taking into account the expectation of high generating household waste, in each section, it was convenient to adopt a procedure to obtain a significant sample of the weight of collected wastes, by means of the following steps:

1. Collection of approximately 400 kg of wastes in the bulk unloaded by a garbage truck in a reserved area of São Carlos's sanitary landfill. That weight was gauged in a Toledo weighing scale, manufactured in Brazil, model 2095 dd/IU, and then disposed on a plastic canvas measuring 8 m x 10 m;
2. The sample was separated in four heaps of 100 kg and the quartering process was applied in each heap. After completing the quartering process the reserved parts were joined for selection of the wastes, according to Figure 2.

2.2.2 Second phase: characterization of the polymeric wastes, post-consumption

This consisted of selecting all of the polymeric wastes, post-consumption - rigid and film plastics - found in the representative sample of conventional collection. The film plastics were gauged by its total weight without segregation of resin type. The rigid plastics were separated by polymeric resin type and reserved. This procedure was performed by sections. The identification of each polymeric waste - rigid plastic - was done by the identification code, in agreement with Table 4, seen in the packing, and, in lack of this, by a group of comparative tests of the characteristics and properties of the polymers up to identification.

The identification tests for the polymers, through characteristic correlation and property, were used few times in wastes that did not have an identification code, and only to distinguish the wastes of HDPE and PP. In this research the following tests were employed.

Correlation with products whose packings usually use known polymers and mechanical behavior as hardness and whitening in the fold.

In the characterization of rigid plastics wastes, in volume, the procedure it was by means of the following steps:

- It was used all of the polymeric wastes, post-consumption - rigid and film plastics - found in the representative sample of conventional collection.
- The chosen sample of each polymeric waste was inserted in container acquainted volume fulfilling the internal volume.
- The volume was considered in the loose condition, or no compressed.

3. RESULTS

The obtained results comprehend the percentage indexes, in weight and volume, per section of the conventional collection and per climatic station, of the rigid and film plastics, presented in Table 5 and 8, and of the polymeric resins of the rigid plastic, in Tables 7 and 9

Table 10 presents the minimum and maximum mean temperatures, and general means of the days of generation of household wastes in the winter and summer climatic stations.

Table 6. Indexes of polymeric wastes - rigid and film plastic - for type of plastic, generated in the municipality of São Carlos, SP, in weight percentage. Conventional collection.

Statistical parameter	Winter		Summer		General mean	
	Type of plastic					
	Rigid	Film	Rigid	Film	Rigid	Film
Mean	2,76	6,43	2,92	8,84	2,84	7,63
Deviation-standard	0,67	1,67	1,01	1,55	0,76	1,20

Table 7. Indexes of the polymeric wastes, post-consumption - rigid plastics - for resin type, generated in the municipality of São Carlos, SP, in weight percentage. Conventional collection.

Resin	Winter		Summer		General mean	
	Mean	Deviation-standard	Mean	Deviation-standard	Mean	Deviation-standard
PET	36,74	5,84	35,19	8,10	35,96	4,88
HDPE	28,58	4,22	24,25	5,38	26,42	3,07
PVC	3,76	2,85	3,77	3,42	3,76	2,30
LDPE	1,69	2,27	1,89	1,09	1,79	1,31
PP	17,36	3,36	15,14	3,87	16,25	2,78
PS	6,29	3,91	9,64	6,37	7,96	4,71
OTHER	5,58	4,12	10,13	8,74	7,85	5,13

Table 8. Indexes of polymeric wastes - rigid and film plastic - for type of plastic, generated in the municipality of São Carlos, SP, in volume percentage. Conventional collection

Statistical parameter	Winter		Summer		General mean	
	Type of plastic					
	Rigid	Film	Rigid	Film	Rigid	Film
Mean	12,40	17,07	12,74	12,17	12,57	14,62
Deviation-standard	4,08	6,22	5,30	2,26	3,51	3,92

Table 9. Indexes of the polymeric wastes, post-consumption - rigid plastics - for resin type, generated in the municipality of São Carlos, SP, in volume percentage. Conventional collection

Station Climate	Statistical parameter	PET	HDPE	PVC	LDPE	PP	PS	OTHER
Winter	Mean	42,92	24,99	4,91	0,41	17,75	6,74	2,28
	Deviation-standard	7,70	6,55	10,88	0,56	5,20	4,78	2,97
Summer	Mean	46,17	21,71	0,78	2,42	18,29	7,49	3,14
	Deviation-standard	12,72	5,40	0,40	3,87	5,57	6,14	3,94
Mean between stations	Mean	44,55	23,35	2,84	1,42	18,02	7,11	2,71
	Deviation-standard	6,08	3,11	5,51	2,07	3,57	4,03	2,45

Table 10. Temperatures in the days of generation of HW, for characterized section of the conventional collection. (<http://br.weather.com>)

Statistical parameter	Temperatures (°C)								
	Winter			Summer			Difference between stations		
	Minim	Maxim	Mean	Minim	Maxim	Mean	Minim	Maxim	Mean
Mean	10,5	23,1	15,8	15,3	28,5	21,3	4,9	5,4	5,5
Deviation-standard	1,25	1,28	1,74	1,54	1,13	1,35	1,68	1,35	1,68

4. CONCLUSIONS

It was determined that the polymeric wastes, post-consumption, of conventional collection of São Carlos/SP, present a percentage of 10,47% of the HW weight, made up of 2,84% of rigid plastics and 7,63% of film plastic. These results show that the participation of polymeric wastes, post-consumption, in HW, is still significant, seeing that the municipality possesses a selective collection system in 60% of the urban area and such outcomes are very close to the results of other cities that only possess conventional collection systems.

In the characterization of polymeric solid wastes, post-consumption - rigid plastics - a composition was determined, in weight, by resin type, with PET (35,96%), HDPE (26,42%), PP (16,25%), PS (7,96%), Others (7,85%), PVC (3,76%), and LDPE (1,79%).

PET is the resin of post-consumption packings with the largest percentage participation in conventional collection, which confirms the increasing generation tendency already observed in the results obtained by such characterizations accomplished in other Brazilian cities.

It was determined that the polymeric wastes, post-consumption, of conventional collection, present a percentage of 27,19% of the HW volume, made up of 12,57% of rigid plastics and 14,62% of film plastics. In the characterization of rigid plastics wastes, a composition was determined, in volume, by resin type, with PET (44,55%), HDPE (23,35%), PP (18,02%), PS (7,11%), PVC (2,84%), Others (2,71%), and LDPE (1,42%).

During the characterizing period of the polymeric wastes, post-consumption, in conventional collection, a mean temperature of 15,8 °C was registered in the winter period, and of 21,3 °C in the summer. The temperature difference between stations was registered at 5,5 °C. Such registrations indicate that the temperatures are very close and that, in-between climatic stations, the differences are enough to alter the habits of the population.

It was verified that the municipal government of São Carlos, SP, engages in developing environmental policies through actions and protection programs for the environment. It is necessary, however, to minimize the indexes of collected polymeric wastes destined to the sanitary landfill, which, in order to accomplish this, it is recommended that the selective collection system undergo restructuring, involving initiative actions as:

- 100% enlargement of the urban area and elevation of the collection frequency of each neighborhood, through the creation of new cooperatives, and increase of the number of waste collector cooperators;
- Enlargement of the logistic and organizational support for the cooperative enterprises of waste collectors;
- Fiscal incentive and technological support for implantation of recycling micro-companies, with priority for low income populations;
- Advertising campaigns and valorization of initiatives that strive for environmental education of the population, focusing on reducing dissipation and separation of the wastes.

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