Revista Gestão & Sustentabilidade
ISSN 2596-142X

Assessing of Manual Sorting in Municipal Solid Waste: A Study Case in São Paulo City

Saiuri Anzei Andrade[1]

Giulliana Mondelli[2]

Abstract
The dependence of political factors and the lack of integrated municipal waste (MSW) management in metropolitan regions of developing countries turn selective collection and circular economy great challenges to be implemented. This paper presents the characterization of the selective household MSW sent to a manual sorting plant located in the central area of the São Paulo City, aiming to assess the real rejects that are going to sanitary landfill after sorting process. Six sampling campaigns were carried out at the input and output of the sorting process during a year (2016 to 2017). The results show that the materials from the selective collection destined to the plant already arrive with 13.8 % of rejects. In addition, there are about 49.8 % of dry and recycled materials after the sorting process, half of them without commercial value, technical recycling solution available or non-identified. This study shown that, independent of the efficiency and social problems in the totally manual sorting process, which was higher than the local Materials Recovery Facilities, the lack of recycling industries and the presence of dry, but not recyclable materials, as composite packaging, non-identified plastics, Styrofoam and electronics difficult the profitability of this kind of plant.

Palavras-chave: Recycling; Gravimetry; Selective Collection; Rejects; Waste Pickers.

Avaliação da Triagem Manual de Resíduos Sólidos Urbanos: Um Estudo de Caso no Município de São Paulo

Resumo
A dependência de fatores políticos e a falta de gestão integrada de resíduos sólidos urbanos (RSU) nas regiões metropolitanas dos países em desenvolvimento tornam a coleta seletiva e a economia circular grandes desafios a serem implementados. Este artigo apresenta a caracterização dos RSU domiciliares seletivos enviados para uma estação de triagem manual localizada na região central da cidade de São Paulo, com o objetivo de avaliar os reais rejeitos que vão para aterro sanitário após o processo de triagem. Foram realizadas seis campanhas de amostragem na entrada e na saída do processo de triagem durante um ano (2016 a 2017). Os resultados mostram que os materiais da coleta seletiva destinados à cooperativa já chegam com 13,8% de rejeitos. Além disso, existem cerca de 49,8% de materiais secos e reciclados após o processo de triagem, metade deles sem valor comercial, solução técnica de reciclagem

[1] Engenheira Ambiental e Urbana pela Universidade Federal do ABC; Brasil, Gerente de Operações da Veolia Serviços Ambientais Ltda.; saiuri.anzei@gmail.com; https://orcid.org/0009-0008-1063-4257; http://lattes.cnpq.br/0614739483450008.

[2] Engenheira Civil pela Universidade Estadual Paulista; Brasil, Professora Assistente do Departamento de Engenharia Civil e Ambiental da Faculdade de Engenharia de Bauru, Unesp; g.mondelli@unesp.br; https://orcid.org/0000-0001-9010-4353; http://lattes.cnpq.br/3712096397575312.

Revista Gestão & Sustentabilidade
ISSN 2596-142X

disponível ou não identificada. Este estudo mostrou que, independentemente da eficiência e dos problemas sociais no processo de triagem totalmente manual, superior às Centrais de Triagem Mecanizadas locais, a falta de indústrias de reciclagem e a presença de materiais secos, mas não recicláveis, como embalagens compostas, plásticos não identificados, isopor e eletrônicos dificultam a rentabilidade desse tipo de planta.

Keywords: Reciclagem; Gravimetria; Coleta Seletiva; Rejeitos; Catadores de Resíduos.

Recebido em: 15/04/2024

Aceito em: 06/05/2024

Publicado em: 06/05/2024

1 Introdução

The municipal solid waste (MSW) is the fraction that considers the generation of waste by the population in their household. As defined by Fischer and Crowe (2000), MSW can also include waste originating from households, commercial activities, office buildings, institutions such as schools and government buildings and small business that dispose of waste at the same facilities used for municipally collected waste.

In Brazil, the National Policy on Solid Waste defines MSW as those derived from domestic activities in urban dwellings and urban cleaning originating from sweeping, street, and public cleaning as well as from other urban cleaning services (BRASIL, 2010). The increase in the generation of this type of waste has been a factor of extreme concern in the last decades since the inappropriate disposal of these is harmful to public health and to the environment.

The generation of MSW can be considered one of the most significant environmental impacts of the modern society, comprising several relevant aspects, such as: discarding and consequent waste of raw material; contamination of soil and water by inadequate disposal; creation of environmental liabilities; proliferation of vector and related diseases, uncontrolled generation of greenhouse gases due to the decomposition of organic matter present among others.

The constant population growth and changing consumption patterns demands a series of actions by the public authorities to mitigate solid waste impacts in the environment. The Law number 12,305 was published in Brazil (2010) aiming the implementation of an integrated solid waste management concept: the use of instruments to increase the practice of

Revista Gestão & Sustentabilidade
ISSN 2596-142X

recycling and reuse of solid waste (that which has economic value and can be recycled or reused) and the final disposal only of the fraction considered as “rejects”.

The MSW management requires the following order of priority: non-generation, reduction, reuse, recycling, waste treatment and environmentally appropriate final disposal of the rejects (BRASIL, 2010). For this purpose, 18 instruments were instituted, which deserve mention of the implementation of tools of shared responsibility, such as selective collection and circular economy; and encouraging the creation and development of places where people without any perspective to be employed could contribute with it.

One of the major challenges facing modern society is the equation of overproduction and a final disposal environmentally correct of solid waste, especially household waste, due to increased generation, inadequate management, and lack of final disposal sites (JACOBI; BESEN, 2011). According to ABREMA (2023), in 2022, 77.1 million tons of MSW were generated in Brazil, maintaining stable during the last 10 years. Of this amount of waste generated in 2022, 61.1 % went to an appropriate final disposal, such as sanitary landfills. The other fraction is directed to controlled and open dumps, increasing the risk of environmental contamination and pollution caused by this activity.

In Brazil, there is an expectation that the percentage of MSW collected and appropriate destined increases. But there is also an apprehension by the public authority and expertise because almost the total of the final disposal of the MSW generated occurs in landfills due to the practicality, the low cost, low segregation of the recyclable materials and no adhesion of the cities to selective collection programs. Although disposal in sanitary landfills is environmentally acceptable, the fact that in Brazil does not yet disposal only the rejects, the useful life of the landfills is reduced and a permanent environmental liability in the region is engender.

To seek solution to this problem in Brazil, public authorities have been working towards the correct destination of MSW, through initiatives aiming the elimination of the final disposal into open and controlled dumps, as well as proposing instruments to reduce the volume of waste disposed in landfills, such as selective collection, biological and thermal treatments. In this way, it is understood that the correct destination will bring not only environmental benefits, but also economic benefits.

However, what is observed in the current national scenario is that the fraction of MSW that is currently disposed in landfills still cannot be characterized only as rejects. For this, it is necessary to strengthen the recycling culture through the practice of the selective collection.

Revista Gestão & Sustentabilidade
ISSN 2596-142X

Recycling, when properly integrated, provide significant benefits, such as the reduction of volumes destined to landfills, reduction of areas of irregular disposal, valuation and reinsertion of waste in production chain and reduction of the need of use of nature resources (PACHOALIN FILHO et al., 2014).

In 2018, only 22 % of the municipalities in Brazil (1,227) operate selective collection programs (CEMPRE, 2019). In addition, most municipalities that already have some type of initiative for the selective collection programs cannot achieve a high rate of segregation of the recycled material among the total MSW generated, since the timid develop actions that are not able to cover the municipally as a whole (ABRELPE, 2020). As determinant factors for this scenario, it is possible to identify the insufficient quantity of fleet and points of delivery of recycled materials destined to the selective collection, the cost 4.6 times higher than the regular collection and no sufficient local sorting plants. It is also observed the incorrect separation of the materials in the generating source (residences), causing the contamination of the recyclable materials. In 2018, 24 % of the total MSW selective collected was considered rejects, followed by 21 % of paper and cardboards, 17 % of plastics, 10 % of aluminum, 9 % of ferrous metals, 8 % of glasses, 2 % of Tetra Pak, 2 % of electronics and 7% of others (CEMPRE, 2019). So, selective collection programs must be totally embracing in other to guarantee the attendance of the entire population of the municipality. In addition, it must guarantee the efficiency of the sorting process in the sorting plants that receive collected materials aiming the low generation of rejects.

In view of this scenario, it is possible to observe that due to the dependence of political factors and the lack of integrated MSW management in Brazil, dumps and controlled dumps persist and are synonymous of environmental impact of soils, waters, and air, besides causing the proliferation of vectors and diseases. In addition, selective collection and reverse logistic have not been yet implemented to ensure a cradle-to-cradle life cycle of the products and a significant fraction of the materials that could be recycled or reused are being sent to the final disposal.

Current interest in the MSW composition comes from the need to monitor material recycling and energy recovery targets. In general, information about waste composition is needed for several purposes from the decision-making concerning waste utilization to the development of local waste management systems and planning information campaigns (SAHIMAA et al., 2015).

Revista Gestão & Sustentabilidade
ISSN 2596-142X

The MSW composition is intrinsically correlated with the degree of development, climatic conditions, socioeconomic and cultural level of a country. Developing countries tend to present higher percentage of organic matter, while upper income countries tend to present more packaging and electronic products (PACHOALIN FILHO et al., 2014).

In Brazil, the global gravimetric composition of MSW, without dry fraction separation by households, has the following characteristics: metals: 2.3 %, papers (10.4 %), glasses (2.7 %), plastics (16.8%), organics (45.3%), since the others 22.5 % are composed by residues that can be considered as rejects (textiles, rubber, sanitaria, multilayer packages), once they don't have sufficient economic value (ABRELPE, 2020).

State of the art of environmental assessment of waste management systems rely on data for the physical-chemical composition of individual material fractions of the study waste (GOTZ et al., 2016). The understanding of the physical composition of the waste is possible through the gravimetric characterization of each fraction of material that composes this waste.

Several authors around the world developed methodologies for sampling and analyzing the waste. However, there is not yet a standardization or standard methodology that has the consensus of all experts in this field of research. Gotz et al. (2016) raises this problem by citing a variety of methods for the characterization of waste that has been developed, but an international consensus has not yet been reached. Due to the heterogeneity of the materials present in the waste as well as the temporal and spatial variability, the representative collection and analysis of waste sample is challenging, laborious and expensive. ASTM D4687 (2014), for example, is a guide to do a waste sample plan, but does not present a methodology for its characterization (ASTM D4687:2014).

The objective of this paper is to assess the selective household MSW sent to a manual sorting plant located at the central region of São Paulo City, considering input and output of the sorting process. This kind of survey is essential to predict futures landfill and demands for recycling and treatment plants, what is required by the National Policy on Solid Waste in Brazil and for the circular economy promotion worldwide, encouraging scientific data obtaining.

2 Material and Methods

2.1 São Paulo City

Revista Gestão & Sustentabilidade
ISSN 2596-142X

The municipality of São Paulo has a population of 12,325,232, according to the last census of the Brazilian Institute of Geography and Statistics of 2020 (IBGE, 2020). Faces huge challenges regarding solid waste management, whose roles and responsibilities permeate everyone involved, from their rulers, the private sector, the third sector and citizens. When the metropolitan region of São Paulo is considered, with more than 21 million inhabitants, it would occupy the position of the fourth largest population on the planet, only behind the great Tokyo, Delhi, and Shanghai, respectively (ONU, 2019).

As for the mass of MSW collected in the municipality, order of 1.1 kg/inhabit/day in 2012, varying significantly between the different sub-municipalities, where there are extremes in the city of Tiradentes and Pinheiros, whose generation per capita was 0.63 and 1.73 kg/inhabitant, respectively (PMSP, 2014a).

Administratively, the municipality is divided into 32 sub-municipalities, characterized as decentralized local management administrative structures (PMSP, 2014b).

The city of São Paulo has three different and complementary approaches to selective collection in the city, namely: “door-to-door” (household), “Ecopoints” (household recycling centers) and partnership with waste pickers sorting plants. Door-to-door selective collection and management of the Ecopoints are conducted by the concessionaires responsible for each region, and as a way of promoting social inclusion, part of the waste collected door to door and in the Ecopoints goes to the sorting plants, besides the waste recyclables collected independently by waste pickers (PMSP, 2019). Table 1 presents the total amounts of the municipality for the regular collection and door-to-door selective collection, during the months those samplings were carried out for the present study.

Table 1: Total MSW collected for the regular collection and door-to-door selective collection, for São Paulo city, as data provided by (PMSP, 2020) during the study months.

Month/year	Total Regular Collection (ton/month)	Door-to-door Total Sellective Collection (ton/month)	Sellective Collection Index (%)
April/2016	298,580	6,975	2.34
May/2016	294,472	6,887	2.34
August/2016	297,554	7,092	2.38
October/2016	293,485	6,818	2.32
January/2017	318,771	8,098	2.54
February/2017	286,865	6,969	2.43
Average	**298,288**	**7,140**	**2.39**

Revista Gestão & Sustentabilidade
ISSN 2596-142X

2.2 Plant Selection for MSW Sampling

The selection of the sorting plant for the MSW sampling from the household selective collection in the São Paulo City was based on the following criteria: location, type of waste that was received and sorted and location of the sub-municipality from which the waste was collected. Based on those criteria, of the 20 manual plants present in the São Paulo City that works with MSW, the Coopere Sorting Plant was chosen for the collection of samples for the characterization. Located in the Central Region of São Paulo City, Coopere is responsible for receiving and performing the manual sorting of the material coming from the door-to-door selective collection, classified as dry MSW selective by community that lives in the Sé Sub-municipality. Sé Sub-municipality represents an area of 25.56 km² and has 431,106 inhabitants, with a population density of 16,866 inhabit/ km² (PMSP, 2017). Sé Sub-municipality has the fifth best M-HDI (Municipal Human Development Index) of the municipality (MOREIRA, 2017), of 0.906, which considers income, education, and longevity of the population, besides being the one that most participates in the municipality selective collection.

Around 130 tons of dry MSW are sent to Coopere Sorting Plant per month (MOREIRA, 2017), came from door-to-door selective collection, what represent 1.82 % from the total door-to-door selective collection of the municipality (Table 1). Besides materials composed of paper, plastic, metals and glass, electronical devices and aerosols are also received. Average storage times vary by type: one week for paper and cardboard, ten days for ferrous metals, fifteen days for glass and one month for plastics. The waste sorted stay disposed in a covered place and is removed by the municipal service every 2 or 3 days to the sanitary landfill (MOREIRA, 2017).

2.3 MSW Sampling

MSW samples were collected in the input and output of the manual sorting process carried out by pickers, those persons the make the manual selection in a treadmill. The Coopere Sorting Plant has two treadmills for sorting materials by the pickers, called as Production Line 1 and Production Line 2. So, the MSW received is divided between the two lines as demonstrate as bellow:

1) Piles 1 and 2 (P1 and P2) with the received door-to-door dry MSW;
2) From the Piles 1 and 2, the MSW bags are handling and send to the treadmills 1 and 2 (IT1 and IT2, respectively);

Revista Gestão & Sustentabilidade
ISSN 2596-142X

3) Manual sorting of the recycling materials by the pickers in both treadmills;
4) Output of the materials after sorting in treadmills 1 and 2 (OT1 and OT2, respectively) or "true" rejects;
5) Handling rejects to a single pile (Rejects Pile - RP) to be transported to the sanitary landfill.

MSW samples were collected at each stage of the sorting process described above (Fig. 1), totaling 6 sampling campaigns performed over a 10-month period, randomly (month/day/year): 04/02/2016, 05/27/2016, 08/22/2016, 10/21/2016, 01/27/2017 and 02/02/2017.

As can be seen in Figure 1, sample 1 represents the collection of material in different points of P1 + P2, that is, collection in the storage piles of the material from the household selective collection (input). Similarly, sample 2 represents the collection of material at the time of entry into the input treadmills 1 and 2 (IT1 and IT2), when P1 and P2 are handled and mixed. Sample 3 represents the collection of the rejects immediately after the output of the treadmills 1 and 2 (OT1 and OT2). Finally, sample 4 represents the collection of the waste in the pile that will be destined for the sanitary landfill, or the final rejects pile (RP). It is noteworthy that the MSW sampling was made randomly in several points of the piles but trying to incorporate the largest variety of waste as possible.

The strategy for the collection of samples was established to characterize the input and output materials after technical visits carried out at the chosen plant. The samplings aimed to carry out in-situ comparisons on specific dates, to find what was being sorted out and effectively generated as rejects. So, a collection schedule was established every around two months, to cover the seasonality of the consume costumes. A 100 L bag for each sampling spot was collected at random as a composite sample to represent as much faithfully as possible the total waste processed by the facilities over the scheduled collections, according to the Brazilian Standard ABNT NBR 10.007 (2004). After collections, the samples were transported at the same day to the laboratory where they were stored at room temperature for the gravimetric analysis.

2.4 Gravimetric Analysis

The gravimetric composition was performed according to the sorting process carried out by the Coopere Sorting Plant.

Revista Gestão & Sustentabilidade
ISSN 2596-142X

Each of the four samples collected in each campaign (P1+P2, IT1+IT2, OT1+OT2, RP) had their materials segregated according to the typology established by the local workers. The chosen laboratory bench was waterproofed and tagged with the identification of each classification.

Figure 1: Pictures of the sampling spots at Coopere Sorting Plant, São Paulo City, Brazil: a) Pile 1, b) Pile 2, c) Input Treadmill 1, d) Input Treadmill 2, e) Output Treadmill 1 and Treadmill 2, f) Rejects Pile.

2.5 Material Recovery Yields

In order to analyze the Coopere Sorting Plant data, Material Recovery Yields (MRY) were calculated from the amount of waste screened and segregated for recycling

Revista Gestão & Sustentabilidade
ISSN 2596-142X

{[(P1+P2)+(IT1+IT2)]/2}-{[RP+(OT1+OT2)]/2} divided by the total amount of the input waste [(P1+P2)+(IT1+IT2)] reaching the MRF, as represented by Equation 1:

$$MRY = \frac{\{[(\mathrm{P1} + \mathrm{P2}) + (\mathrm{IT1} + \mathrm{IT2})]/2\} - \{[\mathrm{RP} + (\mathrm{OT1} + \mathrm{OT2})]/2\}}{(\mathrm{P1} + \mathrm{P2}) + (\mathrm{IT1} + \mathrm{IT2})} * 100 \quad (1)$$

This way, if MRY is positive, inputs were higher than the outputs, and the referred material was sold for recycling. If MRY is zero or low, is estimated that the inputs are the same of the output, doesn´t occurring the recycling. And finally, if MRY is negative, the output was higher than the input, what means that material is considered reject and goes to the landfill. Is important to note here that samplings of the input (I) and output (O) were collect at the same day, but not guarantee the same processed waste at the beginning and final of the process, and because of that can be occur variations on these values.

3 Results and Discussion

Tables 2a and 2b presents the whole data obtained during the study, with the quantities and MRY calculated for the 6 samplings campaigns for each sampled spot (P1+P2, IT1+IT2, OT1+OT2, RP), considering the 32 typologies initially established by the Coopere Sorting Plant. These results show high mass difference for paper, scrap, glasses, textiles and rejects, and some seasonal quantities for composite packaging. Some unusual materials also appear in the gravimetric characterization seasonality, as aerosols, scrap, white glasses, electronic materials, rubbers, and woods. How plastics have lighter weight, their values are lower and, consequently, less variable, and heterogeneous during the carried-out campaigns.

Table 3 presents the arithmetical averages and percentages of the 6 campaigns for each sampled spot and for the MRY values. Materials with negative MRY values or non-commercialized by the Plant were organized in the inferior part of this Table, which also presents the total masses of the materials considered commercialized (1 to 22), non-commercialized (23 to 28) and real rejects (29 to 32).

Observing crude data in Tables 2a and 2b, Campaigns 3 and 4 revealed very great amounts of composite packaging at OT1+OT2. About the percentage of the materials that could be recycled, the following stand out for RP: plastic (22%), paper (10%), Styrofoam (5%), metal (2%), Tetra Pak and glass, together, (1%), values close to those found in the

Revista Gestão & Sustentabilidade
ISSN 2596-142X

(OT1+OT2) samples, summing 40 %. At these output spots, it was possible to observe the presence of recyclable materials in the final waste, mainly plastic, paper and Styrofoam.

After determining the final mass by typology defined in Tables 2a, 2 b and 3, the 32 typologies predetermined were grouped according to the material affinity and were classified into only 9 classifications to better analyze these data:

1) Papers: Paper, Newspapers, Magazines and Cardboard;
2) Tetra Pak;
3) Metals: Aluminum and Steel;
4) Plastics: PP, PET, PVC, HDPE, LDPE, Other, Unidentified and bags;
5) Glasses: White and Colorful;
6) Styrofoam;
7) Composite Packaging;
8) Electronics: electronic materials and CDs;
9) Rejects: rejects, textiles, wood, rubber.

Revista Gestão & Sustentabilidade
ISSN 2596-142X

Table 2a: Detailed gravimetric composition of the dry MSW samples for Campaigns 1 to 3 carried out at Coopere Sorting Plant (in grams).

Campaign # - Date	**1 - 02 March 2016**					**2 - 27 May 2016**					**3 - 22 August 2016**				
Typology	**P1+P2**	**IT1+IT2**	**OT1+OT2**	**RP**	**MRY**	**P1+P2**	**IT1+IT2**	**OT1+OT2**	**RP**	**MRY**	**P1+P**	**IT1+IT2**	**OT1+OT2**	**RP**	**MRY**
Paper	429.55	208.70	264.91	578.80	**-0.32**	154.49	142.96	8.13	0.00	**0.97**	2.835.09	104.26	81.09	40.55	**0.96**
Paper packaging	282.15	88.58	95.82	281.35	**-0.02**	249.54	0.00	7.20	0.00	**0.97**	236.78	208.48	41.74	202.53	**0.45**
Cardboard	516.03	102.70	381.44	219.50	**0.03**	559.40	405.61	17.33	0.00	**0.98**	0.00	0.00	69.55	0.00	**NC**
Newspaper	4.58	0.00	11.72	66.93	**-16.17**	44.53	29.06	0.00	0.00	**1.00**	0.00	18.32	0.00	41.89	**-1.29**
Magazine	0.00	0.00	7.45	0.00	**NC**	67.08	77.02	0.00	0.00	**1.00**	0.00	198.54	0.00	116.53	**0.41**
Tetra Pak	173.89	289.46	69.13	46.75	**0.75**	69.50	76.62	10.01	0.00	**0.93**	67.77	445.32	39.91	111.44	**0.71**
Scrap	335.13	0.00	0.00	0.00	**1.00**	0.00	1300.00	19.48	0.00	**0.99**	0.00	0.00	0.00	0.00	**NC**
Aluminum	13.22	51.14	12.14	17.75	**0.54**	121.28	0.00	0.00	0.00	**1.00**	14.70	14.70	0.00	0.00	**1.00**
Aerosols	0.00	0.00	0.00	0.00	**NC**	0.00	54.45	0.00	0.00	**1.00**	0.00	88.24	0.00	0.00	**1.00**
Steel cans	0.00	88.87	133.30	0.00	**-0.50**	0.00	116.43	0.00	0.00	**1.00**	0.00	183.56	14.10	0.00	**0.92**
White glass	0.00	0.00	0.00	0.00	**NC**	0.00	0.00	0.00	0.00	**NC**	0.00	254.16	0.00	0.00	**1.00**
Color Glass	377.08	639.83	79.73	16.53	**0.91**	606.32	383.67	0.00	0.00	**1.00**	0.00	848.22	121.39	0.00	**0.86**
PET	110.00	378.39	127.28	312.20	**0.10**	252.11	377.53	109.39	157.48	**0.58**	334.62	295.33	42.52	286.49	**0.48**
HDPE	366.28	250.65	88.19	74.64	**0.74**	207.72	500.41	0.00	0.00	**1.00**	278.09	0.00	28.46	44.54	**0.74**
Colorful market bags	180.00	173.68	35.33	105.00	**0.60**	142.76	51.19	0.00	0.00	**1.00**	59.50	217.21	0.00	8.55	**0.97**
Black trash bags	0.00	235.50	0.00	0.00	**1.00**	0.00	0.00	0.00	0.00	**NC**	0.00	81.61	72.42	0.00	**0.11**
CD	0.00	0.00	0.00	0.00	**NC**	0.00	0.00	0.00	0.00	**NC**	0.00	0.00	0.00	0.00	**NC**
PVC	0.00	0.00	0.00	90.00	**NC**	0.00	0.00	41.28	0.00	**NC**	0.00	35.14	0.00	0.00	**1.00**
LDPE	66.85	56.40	22.78	191.69	**-0.74**	21.81	20.30	17.77	0.00	**0.58**	9.08	24.06	20.41	51.86	**-1.18**
PP (fine)	0.00	0.00	0.00	52.66	**NC**	31.96	0.00	34.07	51.01	**-1.66**	9.19	52.14	27.32	86.50	**-0.86**
PP (coarse)	165.00	24.76	150.13	65.98	**-0.14**	47.00	0.00	5.67	28.29	**0.28**	25.58	49.29	54.36	0.00	**0.27**
PS	5.78	0.00	0.00	0.00	**1.00**	0.00	0.00	0.00	0.00	**NC**	0.00	0.00	0.00	0.00	**NC**
Other Plastics	51.49	48.25	106.87	74.35	**-0.82**	109.54	3.58	19.64	52.97	**0.36**	68.78	82.61	5.28	81.51	**0.43**
PS cups	10.93	42.67	45.44	52.13	**-0.82**	15.00	0.00	1.89	0.00	**0.87**	12.66	6.14	0.00	7.88	**0.58**
Styrofoam	86.07	9.80	63.75	251.00	**-2.28**	6.33	59.20	59.20	172.90	**-2.54**	12.25	162.29	57.57	117.07	**0.00**
Electronics	0.00	0.00	0.00	66.52	**NC**	0.00	0.00	0.00	0.00	**NC**	0.00	23.31	0.00	0.00	**1.00**
Textiles	0.00	0.00	28.45	89.53	**NC**	0.00	152.46	0.00	148.33	**0.03**	323.43	96.67	40.69	240.00	**0.33**
Composite packaging	0.00	7.30	32.26	201.29	**-31.01**	0.00	178.46	3.79	111.75	**0.35**	19.45	179.90	2,346.83	7.53	**-10.81**
Rejects	297.30	0.00	136.40	996.27	**-2.81**	1.000.00	0.00	975.04	888.31	**-0.86**	170.14	300.00	91.07	1000.00	**-1.32**
Unidentified plastics	145.00	135.80	79.54	325.17	**-0.44**	377.06	34.70	0.00	170.95	**0.58**	0.00	0.00	45.07	200.00	**NC**
Rubber	0.00	84.33	0.00	100.00	**-0.19**	0.00	0.00	0.00	0.00	**NC**	0.00	0.00	0.00	0.00	**NC**
Wood	0.00	0.00	7.44	325.77	**NC**	0.00	0.00	39.03	0.00	**NC**	0.00	131.02	0.00	0.00	**1.00**
Final Mass (g)	**3,616.32**	**2,916.80**	**1,979.49**	**4,601.81**	-	**4,083.39**	**3,963.64**	**1,368.89**	**1,781.98**	-	**4,477.08**	**4,100.51**	**3,199.77**	**2,644.85**	-

Revista Gestão & Sustentabilidade
ISSN 2596-142X

Table 2b: Detailed gravimetric composition of the dry MSW samples for Campaigns 1 to 3 carried out at Coopere Sorting Plant (in grams).

Campaign # - Date	4 - 21 October 2016					5 - 27 January 2017					6 - 03 February 2017				
Typology	**P1+P2**	**IT1+IT2**	**OT1+OT2**	**RP**	**MRY**	**P1+P2**	**IT1+IT2**	**OT1+OT2**	**RP**	**MRY**	**P1+P**	**IT1+IT2**	**OT1+OT2**	**RP**	**MRY**
Paper	215.00	380.00	100.00	15.00	**0.81**	10.00	25.00	15.00	0.00	**0.57**	20.00	60.00	0.00	5.00	**0.94**
Paper packaging	155.00	60.00	55.00	110.00	**0.23**	445.00	70.00	70.00	55.00	**0.76**	195.00	180.00	215.00	0.00	**0.43**
Cardboard	175.00	940.00	0.00	780.00	**0.30**	75.00	0.00	0.00	0.00	**1.00**	85.00	0.00	0.00	0.00	**1.00**
Newspaper	15.00	0.00	0.00	0.00	**1.00**	0.00	0.00	0.00	0.00	**NC**	0.00	0.00	0.00	0.00	**NC**
Magazine	0.00	0.00	0.00	0.00	**NC**	0.00	0.00	30.00	0.00	**NC**	0.00	179.00	0.00	0.00	**1.00**
Tetra Pak	485.00	170.00	0.00	0.00	**1.00**	195.00	205.00	0.00	0.00	**1.00**	355.00	235.00	0.00	70.00	**0.88**
Scrap	0.00	0.00	0.00	0.00	**NC**	0.00	0.00	0.00	0.00	**NC**	0.00	0.00	0.00	0.00	**NC**
Aluminum	10.00	0.00	5.00	0.00	**0.50**	70.00	50.00	0.00	0.00	**1.00**	15.00	30.00	0.00	10.00	**0.78**
Aerosols	0.00	0.00	0.00	0.00	**NC**	0.00	0.00	0.00	0.00	**NC**	0.00	0.00	0.00	30.00	**NC**
Steel cans	0.00	40.00	0.00	0.00	**1.00**	40.00	0.00	0.00	0.00	**1.00**	40.00	85.00	0.00	0.00	**1.00**
White glass	835.00	0.00	0.00	0.00	**1.00**	0.00	0.00	0.00	0.00	**NC**	275.00	0.00	0.00	0.00	**1.00**
Color Glass	0.00	0.00	0.00	0.00	**NC**	0.00	0.00	0.00	0.00	**NC**	0.00	395.00	0.00	0.00	**1.00**
PET	470.00	115.00	255.00	85.00	**0.42**	295.00	375.00	135.00	30.00	**0.75**	325.00	430.00	100.00	80.00	**0.76**
HDPE	110.00	0.00	45.00	30.00	**0.32**	45.00	95.00	0.00	35.00	**0.75**	55.00	5.00	0.00	0.00	**1.00**
Colorful market bags	30.00	5.00	0.00	10.00	**0.71**	105.00	90.00	0.00	0.00	**1.00**	40.00	50.00	0.00	0.00	**1.00**
Black trash bags	45.00	115.00	0.00	0.00	**1.00**	0.00	50.00	0.00	0.00	**1.00**	0.00	35.00	0.00	0.00	**1.00**
CD	0.00	0.00	0.00	0.00	**NC**	0.00	0.00	0.00	0.00	**NC**	0.00	0.00	0.00	0.00	**NC**
PVC	0.00	0.00	0.00	0.00	**NC**	0.00	0.00	0.00	0.00	**NC**	0.00	0.00	0.00	0.00	**NC**
LDPE	50.00	180.00	25.00	0.00	**0.89**	20.00	85.00	5.00	15.00	**0.81**	35.00	50.00	20.00	20.00	**0.53**
PP (fine)	60.00	120.00	0.00	0.00	**1.00**	60.00	60.00	15.00	45.00	**0.50**	30.00	50.00	35.00	120.00	**-0.94**
PP (coarse)	0.00	0.00	0.00	0.00	**NC**	15.00	70.00	45.00	20.00	**0.24**	95.00	5.00	0.00	30.00	**0.70**
PS	20.00	25.00	35.00	35.00	**-0.56**	35.00	0.00	0.00	0.00	**1.00**	0.00	0.00	0.00	0.00	**NC**
Other Plastics	155.00	150.00	295.00	180.00	**-0.56**	10.00	70.00	30.00	165.00	**-1.44**	2.00	15.00	0.00	45.00	**-1.65**
PS cups	0.00	5.00	5.00	5.00	**-1.00**	0.00	5.00	0.00	0.00	**1.00**	0.00	5.00	0.00	10.00	**-1.00**
Styrofoam	140.00	80.00	100.00	40.00	**0.36**	65.00	0.00	40.00	30.00	**-0.08**	25.00	15.00	45.00	175.00	**-4.50**
Electronics	0.00	0.00	0.00	0.00	**NC**	0.00	0.00	0.00	0.00	**NC**	0.00	0.00	0.00	0.00	**NC**
Textiles	35.00	180.00	20.00	405.00	**-0.98**	0.00	5.00	595.00	980.00	**-314.00**	0.00	20.00	0.00	275.00	**-12.75**
Composite packaging	5.00	0.00	1,590.00	40.00	**-325.00**	85.00	0.00	55.00	25.00	**0.06**	0.00	35.00	25.00	0.00	**0.29**
Rejects	425.00	1305.00	0.00	2,815.00	**-0.63**	175.00	379.00	1460.00	890.00	**-3.24**	65.00	90.00	3400.00	1,530.00	**-30.81**
Unidentified plastics	0.00	0.00	0.00	0.00	**NC**	245.00	39.00	50.00	305.00	**-0.25**	0.00	130.00	300.00	115.00	**-2.19**
Rubber	0.00	0.00	0.00	250.00	**NC**	0.00	0.00	5.00	0.00	**NC**	0.00	0.00	0.00	0.00	**NC**
Wood	0.00	0.00	0.00	0.00	**NC**	0.00	0.00	0.00	0.00	**NC**	0.00	5.00	0.00	0.00	**1.00**
Final Mass (g)	**3,435.00**	**3,870.00**	**2,530.00**	**4,800.00**	**0.00**	**1,990.00**	**1,673.00**	**2,550.00**	**2,595.00**	-	**1,657.00**	**2,104.00**	**4,140.00**	**2,515.00**	-

Revista Gestão & Sustentabilidade
ISSN 2596-142X

Table 3: Averages and percentages and totals obtained for the 6 Campaigns carried out at Coopere Sorting Plant, São Paulo City, Brazil.

Typology	Averages of the Campaigns (g)					Percentages in Mass (%)			
	P1+P2	IT1+IT2	OT1+OT2	RP	MRY (g/g)	P1+P2	IT1+IT2	OT1+OT2	RP
1- Paper	610.7	153.5	78.2	106.6	**0.7**	19.0	4.9	3.0	3.3
2 - Paper packaging	260.6	121.4	80.8	108.1	**0.5**	8.1	3.9	3.1	3.4
3 - Cardboard	235.1	241.4	78.1	166.6	**0.7**	7.3	7.7	3.0	5.2
4 - Newspaper	10.7	7.9	2.0	18.1	**-3.9**	0.3	0.3	0.1	0.6
5 - Magazine	11.2	75.8	6.2	19.4	**0.8**	0.3	2.4	0.2	0.6
6 - Tetra Pak	224.4	236.9	19.8	38.0	**0.9**	7.0	7.6	0.8	1.2
7 - Scrap	55.9	216.7	3.2	0.0	**1.0**	1.7	6.9	0.1	0.0
8 - Aluminum	40.7	24.3	2.9	4.6	**0.8**	1.3	0.8	0.1	0.1
9 - Aerosols	0.0	23.8	0.0	5.0	**1.0**	0.0	0.8	0.0	0.2
10 - Steel cans	13.3	85.6	24.6	0.0	**0.7**	0.4	2.7	0.9	0.0
11 - White glass	185.0	50.8	0.0	0.0	**1.0**	5.7	1.6	0.0	0.0
12 - Color Glass	163.9	377.8	33.5	2.8	**0.9**	5.1	12.1	1.3	0.1
13 - PET	297.8	328.5	128.2	158.5	**0.5**	9.3	10.5	4.9	5.0
14 - HDPE	177.0	141.8	26.9	30.7	**0.8**	5.5	4.5	1.0	1.0
15 - Colorful market bags	92.9	97.8	5.9	20.6	**0.9**	2.9	3.1	0.2	0.6
16 - Black trash bags	7.5	86.2	12.1	0.0	**0.8**	0.2	2.8	0.5	0.0
17 - CD	0.0	0.0	0.0	0.0	**NC**	0.0	0.0	0.0	0.0
18 - PVC	0.0	5.9	6.9	41.2	**1.0**	0.0	0.2	0.3	1.3
19 - LDPE	33.8	69.3	18.5	46.4	**0.1**	1.0	2.2	0.7	1.5
20 - PP (fine)	57.9	24.8	42.5	24.0	**0.3**	1.8	0.8	1.6	0.8
21 - PP (coarse)	12.2	4.2	5.8	5.8	**0.5**	0.4	0.1	0.2	0.2
22 - PS	0.0	3.9	0.0	11.1	**1.0**	0.0	0.1	0.0	0.3
23 – Other Plastics	38.2	47.0	18.6	59.2	**-0.4**	1.2	1.5	0.7	1.9
24 - PS cups	66.1	61.6	76.1	99.8	**-0.6**	2.1	2.0	2.9	3.1
25 - Styrofoam	6.4	10.6	8.7	12.5	**-0.1**	0.2	0.3	0.3	0.4
26 -Unidentified plastics	355.4	345.7	1010.4	1353.3	**-6.6**	11.0	11.0	38.4	42.5
27 - Electronics	55.8	54.4	60.9	131.0	**-1.5**	1.7	1.7	2.3	4.1
28 - Composite packaging	127.8	56.6	79.1	186.0	**-0.6**	4.0	1.8	3.0	5.8
29 - Textiles	18.2	66.8	675.5	64.3	**-61.0**	0.6	2.1	25.7	2.0
30 - Rubber	0.0	14.1	0.8	58.3	**-0.2**	0.0	0.4	0.0	1.8
31 - Wood	0.0	22.7	7.7	54.3	**1.0**	0.0	0.7	0.3	1.7
31 - Rejects	59.7	75.7	114.0	356.3	**-65.5**	1.9	2.4	4.3	11.2
Total of Comerciables	2490.4	2378.3	576.1	807.7	-	77.4	75.9	21.9	25.4
Total of Non-Comerciables	312.7	297.0	918.9	552.8	-	9.7	9.5	35.0	17.4
Total of Rejects	415.1	458.1	1,133.0	1,822.2	-	12.9	14.6	43.1	57.3

Based on this classification, the gravimetric composition of the waste of each sampling spot was studied through the representative percentage of each material within the

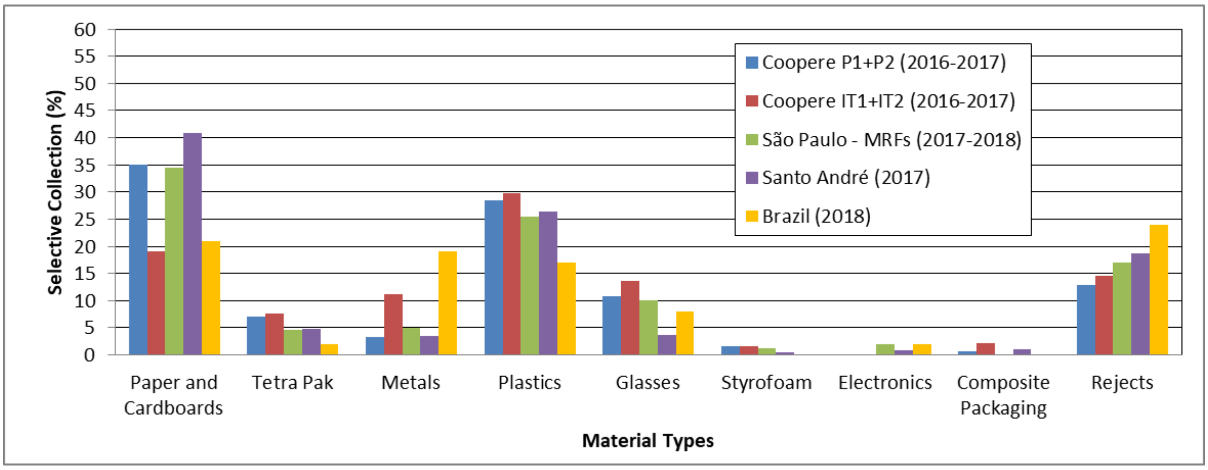
Revista Gestão & Sustentabilidade
ISSN 2596-142X

total mass collected during the campaigns, compared with other studies carried out in Brazil for CEMPRE (2019), Jacinto (2019), Oliveira (2019), SEMASA (2018) and Moura et al. (2018).

Figure 2a presents the average percentage of the input data for this study (P1+P2 and IT1+IT2) for each category listed above, compared with the results of the gravimetric analyses obtained for Selective Collection: in Brazil in 2018 (CEMPRE, 2019); Material Recovery Facilities in operation in São Paulo city (JACINTO, 2019; OLIVEIRA, 2019), data from May 2017 to May 2018; households from Santo André city in 2017 SEMASA (2018), a medium city located in the Metropolitan Region of the São Paulo State, with 721,368 inhabitants (IBGE, 2020) and 40 km distant from São Paulo city.

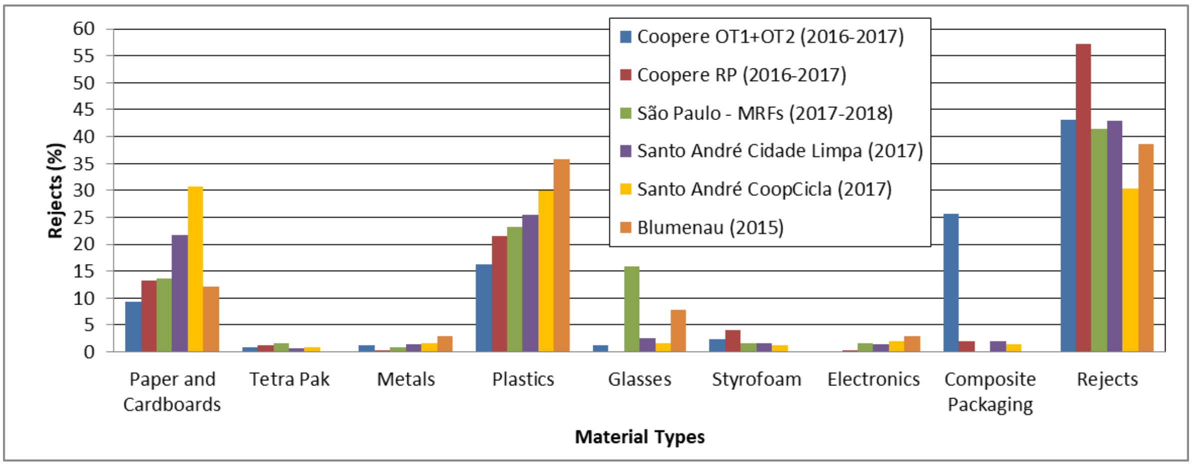
Figure 2b presents the average percentage of the output data for this study (OT1+OT2 and RP) for each category listed above, compared with the results of the gravimetric analyses obtained for rejects in similar study cases carried out in other sorting plants in Brazil: Material Recovery Facilities in operation in São Paulo city (JACINTO, 2019; OLIVEIRA, 2019), data from May 2017 to May 2018; two manual sorting plants located in Santo André city in 2017 SEMASA (2018), Cooperatives Cidade Limpa and CoopCicla; a manual sorting plant located in Blumenau, a medium city located in the South Region of Brazil (MOURA et al., 2018), with 361,855 inhabitants (IBGE, 2020) and 600 km distant from São Paulo city.

Figure 2a: Input data for this study (Coopere P1+P2 and IT1+IT2) compared with the results of the Selective Collection in Brazil (CEMPRE, 2019), in Material Recovery Facilities (MRFs) of the São Paulo city (JACINTO, 2019; OLIVEIRA, 2019) and in Santo André city (SEMASA, 2018).



Revista Gestão & Sustentabilidade
ISSN 2596-142X

Figure 2b: Output data for this study (Coopere OT1+OT2 and RP) compared with the results of the analyzed rejects from the Material Recovery Facilities (MRFs) of the São Paulo city (JACINTO, 2019; OLIVEIRA, 2019), Cooperatives Cidade Limpa and CoopCicla located in Santo André city (SEMASA, 2018) and a manual sorting plant located in Blumenau city (MOURA et al., 2018).



Based on Figure 2a, is noteworthy that the separation or even the consumption of papers, Tetra Pak, plastics, and glasses are higher in the São Paulo city, including the present study (exception for papers of the IT1+IT2), than for the Brazilian average CEMPRE (2019). Santo André presents the same behavior, with exception of the glasses. The opposite can be observed for metals, also considering the MRFs and the municipality of Santo André, as well as the number of rejects that arrive at the sorting plants, frequently constituted by diapers, food debris, pizza packaging, preservative, tissue, among others. It is believed that this fact is due to the large presence of informal collectors in the Metropolitan Region of São Paulo, many of them focused on collecting aluminum cans, of great commercial value, which provides a pre-selection of what arrives at these plants.

The smaller amount of rejects for the present study (12.9 to 14.6 %, Fig. 2a), on the other hand, reveals a higher level of environmental education among the residents of the Sé Sub-municipality, when compared to the average of the population, whether in the São Paulo city or even in Brazil (24 %), since less contaminated materials, even if recyclable, are separated by the households, what corresponds with the higher level of the M-HDI indeed. Electronics, composite packaging, and Styrofoam follow a same order of variation (0 to 2.1 %) in the different studies analyzed.

Revista Gestão & Sustentabilidade
ISSN 2596-142X

Based on Figure 2b, the percentage of the rejects obtained on the final treadmills are very similar (43.1 % for Coopere (OT1+OT2), 41.4 % for MRFs, 43 % for Santo André Cidade Limpa and 38.7 % for Blumenau), with exception of the Coopere RP, reaching 57.3 % of real rejects, and Santo André CoopCicla, with 30.3 %. This behavior of the Coopere RP was expected, since there is another selection of possible commercial materials after the sorting process, mainly of the composite packaging, with is higher at OT1+OT2 (25.7 %) than at RP (2 %). Fig. 2b also reveals that the Coppere sorts more papers, plastics, glasses and electronics, than the other plants surveyed. This shows a higher efficiency of the manual sorting linked with the better separation of the households, when less contaminated recyclables arrived at the plant. The opposite was verified for the Styrofoam, and similar percentages (0 to 4.1 %) were obtained between the different plants for metals, Tetra Pak and composite packaging except OT1+OT2.

Figure 3 presents the results obtained at the four sampling spots at Coopere, aiming the comparison between the input materials to the plant – sum of the values obtained in the collection before the sorting process (P1+P2 and IT1+IT2) – and the output materials as rejects to the landfill – sum of the values after the sorting process (OT1+OT2 and RP).

Figure 3: Gravimetric composition (average %): comparison between Input (before sorting process) and Output (after sorting process).

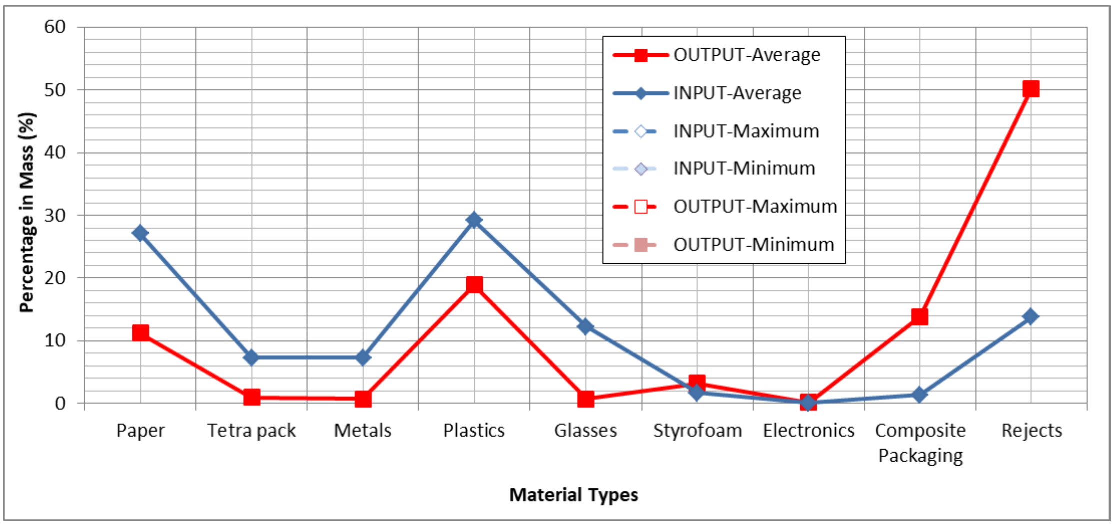


Figure 3 makes it clear that most paper, plastics, metals, Tetra Pak and glasses are sold by the cooperative, continuously. On the other hand, Styrofoam, and electronics, which appear in smaller quantities, do not give significant data in the input and output. However, the

Revista Gestão & Sustentabilidade
ISSN 2596-142X

amount of composite packaging is a problem to be taken to the industries that manufacture it, as there is no technical recycling solution, and they are correctly being separated as dry MSW by the households. Finally, the large number of rejects at the exit (50.2 %) shows efficiency in the work performed by the pickers, as they are still 13.8% at the input.

Although the paper and plastic categories present a lower efficient during the sorting, when output data are compared with input data (Tables 2a, 2b, 3 and Figures 2a, 2b and 3), their presence in the final rejects is significant (11.2 and 18.9 %, respectively). The categories of metals, Tetra Pak and glasses demonstrate less significant percentages in the final rejects, resulting in a greater efficiency during the sorting of these materials. Metals, Tetra Pak, and glasses categories record less significant percentages at the output (Tables 2a, 2b, 3 and Figures 2a, 2b and 3), resulting in greater sorting efficiency of these materials and to have more commercial values.

The Styrofoam presents a peculiar result because, although it is a weightless material and contributes to a small percentage in mass, when compared to the values of other materials, it presents a higher output value (3.2%) than the input (1.7%), meaning that this material is not separated during sorting, despite the difficulty and viability to recycling this material. It is important to remember that the Styrofoam is a very low-density material, which means that occupies larger volume with smaller mass. As the sorting plant sells the material sorted by weight, this may be another factor that discourages sorting of this material, reducing the useful life of the landfills.

When "paper" category is detailed to understand what kind of materials of this category contribute to a high output without final rejects, can be verify that the output of paper packaging, cardboard and newspaper are greater than the input values. Therefore, these are the ones that have the greatest contribution to the final rejects, as observed in Figure 4 and Tables 2a and 2b. Anyway, the great standard deviation for input paper and the small difference between the average percentages for each typology, reveals that many of these materials are correctly separated by the households, but many of them arrives at the plant contaminated by liquids or other products present in the other MSW categories. The independent collection by the selective collection trucks of the papers, plastics, metals and glasses could contribute to increase the papers category recycling.

In Figure 5 and Tables 2a and 2b can be observed that there is a greater predominance of LDPE, PVC, PP, other plastics and unidentified plastics in the output, when compared to the input, indicating that these typologies are less interesting to be recycled that the others,

Revista Gestão & Sustentabilidade
ISSN 2596-142X

such as PET, HDPE, supermarket and black trash bags. Another point of observation is that plastics that did not give the label of their typology on the packaging – and classified in this research as “unidentified” – have a very high percentage in the output. One hypothesis to be considered is the lack of the labeling makes difficult the identification for the pickers, especially from the less common polymers and, because of lack of understanding, this material that could be recycled ends up in the final rejects. Anyway, these materials are also being correctly separated by the households, independent of the packaging and technological solutions that the plastics industries should give for them. The standard deviations calculated in Fig. 5 show a certain uniformity of the sample data obtained, not influencing the analysis above.

Figure 4: Papers Composition (%) – Input average (before sorting process) versus Output average (after sorting process), with standard deviations.

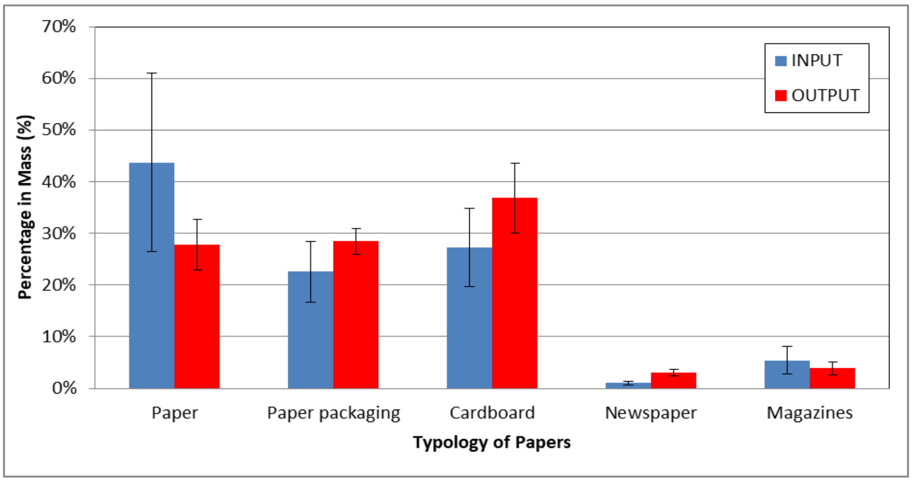
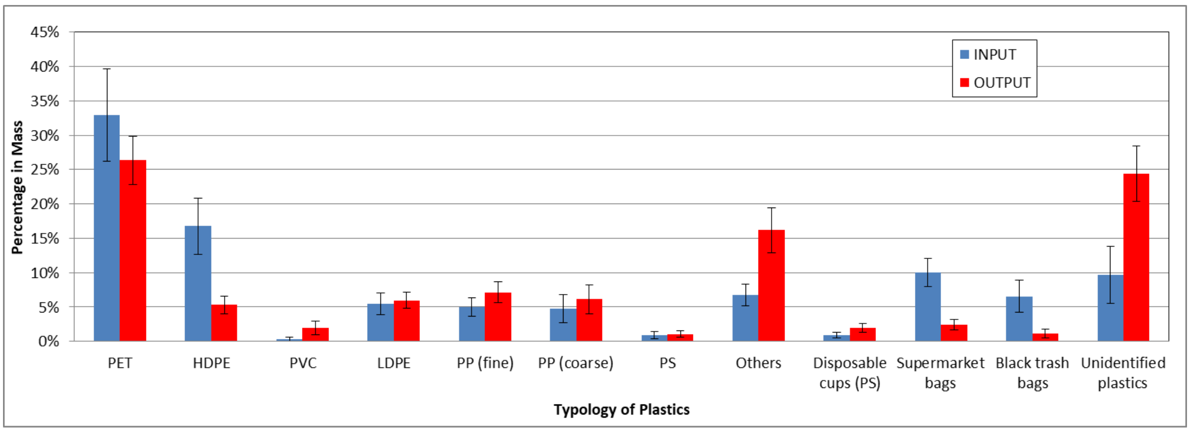


Figure 5: Plastics Composition (%) – Input average (before sorting process) versus Output average (after sorting process), with standard deviations.

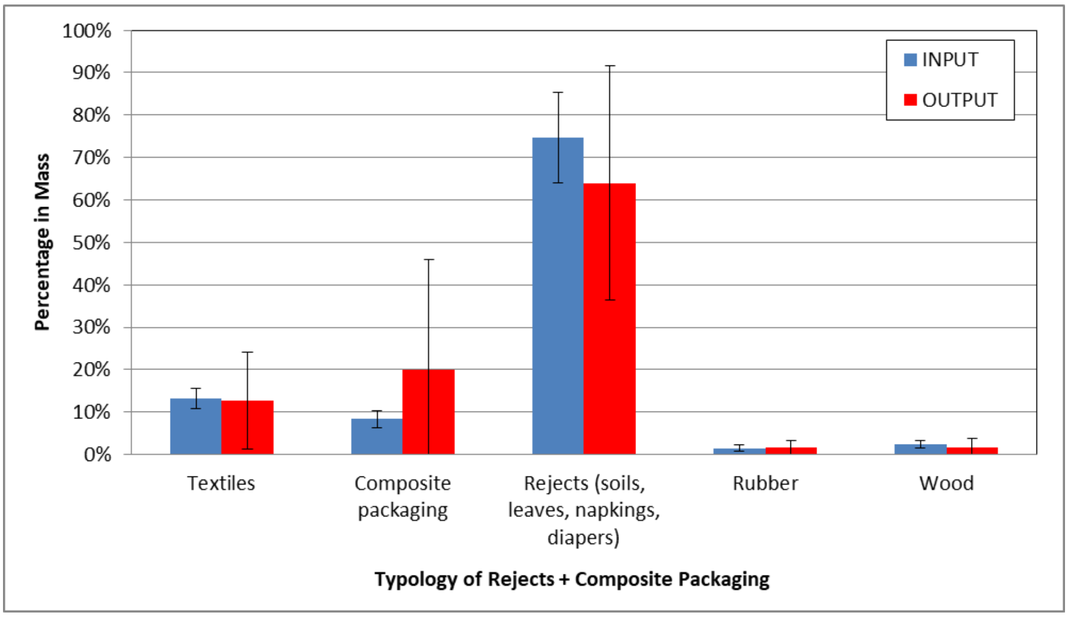


Revista Gestão & Sustentabilidade
ISSN 2596-142X

When analyzing what is considered as reject after the screening process in Fig. 6, the presence of materials that may not be sent by the population to the selective collection is observed, such as: textiles, antique objects (tape k7, fair bags, caps), wood, rubber, and others, but that are "dry", as recommended by the municipality. Textiles correspond to the second largest fraction of the total rejects category, with about 13% both at the input and at the output, being just behind the real rejects (69 %). Many clothes and cloths that tear or can no longer be reused or donated, end up prevailing in selective collection, as there is no viable local solution for their recycling. The same was detected by Moura et al. (2018).

The presence, even minimal, of rubber (many times as footwear) and wood (debris of small constructions), as well as soil (gardening services), used paper napkins, pizza boxes, among others that make up the real waste and could be submitted to energy recovery processes, still reveal a certain lack of information among the population, it is unknown if by mistake or even by ignorance of what selective collection is. The generation of composite packaging, on the other hand, revealed large standard deviations, as well as a significant percentage of the total waste, and there must be a greater look from the industries and consumers for the products that need this type of packaging. Perhaps rethinking consumption is an efficient way to avoid this kind of material, since mostly times their disposal are the landfills and water bodies.

Figure 6: MSW Rejects Composition (%) – Input average (before sorting process) versus Output average (after sorting process), with standard deviations.



Revista Gestão & Sustentabilidade
ISSN 2596-142X

Table 4 presents the final analyses of the situation of the Coopere Sorting Plant, compared with the two Material Recovery Facilities (MRFs) in operation in the city using mechanical equipment, as described and studied by Jacinto (2019) and Oliveira (2019). As confirmed by the MRY calculation, both MRFs sell less typologies than Coopere Sorting Plant. According to Jacinto (2019), in MRF - Ecourbis the following materials are sold: paper, cardboard, Tetra Pak, ferrous metal, non-ferrous metal, PET, HDPE and LDPE. And according to Oliveira (2019), in MRF - Loga the following materials are sold: paper, cardboard, Tetra Pak, ferrous metal, non-ferrous metal, glass, PET, HDPE, PVC and PP.

Table 4: Analyses and quantities of the Coopere Sorting Plant (present study) in comparison with the MRF – Ecourbis (JACINTO, 2019) and MRF – Loga (OLIVEIRA, 2019), all of them in operation in São Paulo city.

Information	**COOPERE (present study)**	**MRF - Ecourbis**	**MRF - LOGA**
Total MSW from Selective Collection (ton/month) [(1)]	130.0	1600.0	1600.0
Commerciale materials before sorting - Input (%) [(2)]	76.6	50.5	76.5
Non-commercial packages before sorting - Input (%) [(2)]	9.6	27.8	10.9
Rejects before sorting - input (%) [(2)]	13.8	21.6	12.5
Commerciale materials after sorting -Output (%) [(2)]	23.6	14.2	46.0
Non-commercial packages after sorting - Output (%) [(2)]	26.2	39.0	18.0
Rejects after sorting - Output (%) [(2)]	50.2	46.8	36.0
Commercialized Materials (ton/month) [(3)]	68.9	581.9	488.9
Commercialization Index by Sorting Plant (%) [(4)]	53.0	36.4	30.6
Total of materials to landfilling (ton/month) [(5)]	61.1	1018.1	1111.1

[(1)] Total mass calculated based on data provides by each Material Recovery Facility (MRF), of 80 ton/day (JACINTO, 2019; OLIVEIRA, 2019) working 20 days/month, and of 130 ton/month for Coopere cited by PMSP (2017);
[(2)] Averages calculated based on Table 3;
[(3)] Total MSW from Selective Collection * (Input – Output of the Commerciale Materials) / 100%;
[(4)] (Commercialized Materials / Total MSW from Selective Collection) * 100%;
[(5)] Total MSW from Selective Collection Commercialized Materials.

Based on the total MSW receipt by each MRF in Table 4 and comparing with the average amount of selective collection in the municipality, of about 7,000 ton/month (Table

Revista Gestão & Sustentabilidade
ISSN 2596-142X

1), both MRFs are responsible for more than 2/3 receipt of the dry MSW door-to-door collected. Therefore, MRFs have a much higher processing condition, with separation equipment imported at the beginning of the process, followed by final manual separation. As well as the fact that MRFs have fewer buyers, the fact that they are larger can hamper their income, as they have lower rejects rates than Coopere at the output (46.8 for MRF – Ecourbis and 36.0 % for MRF – LOGA), indicating less efficiency than the sorting work done entirely by pickers of the Coopere (50.2 %) (Table 4). These data show that, unlike Coopere Sorting Plant, less than half of the dry MSW that arrive at the MRFs are sold to the recycling industries in the municipality and region. Still, 23.6% in output could be sold by the Coopere, and it is not (Table 4).

Jacinto (2019) and Oliveira (2019) found that most recycling industries in the municipality buy paper, cardboard, aluminum, Tetra Pak, and HDPE. The Covid-19 pandemic has brought many difficulties to the sector, since many manual cooperatives have ceased to operate 2020 and only the MRFs operated for a while, increasing their receipt even. Even so, this study shows that there is a repressed demand for several other materials, such as all other types of plastics, electronics, and glass, and well separated by the population, which could have a better market value, thus increasing the efficiency of the sorting plants of the municipality.

Independent of the public regulations and social aspects, as practical destination to be applied to the materials identified in the present study those are going to the landfills, is suggested, in accordance with Jacinto (2019), Oliveira (2019) and Moura et al. (2018) for the Brazilian reality:

1) Real rejects, rubber, wood, textiles, composite packaging, paper packaging, newspaper, contaminated blank paper and cardboards, unidentified and other plastics, PVC, LDPE, PS, Styrofoam: energy recovery process as incineration plants and Mechanical-Biological Plants for Residue Derived Fuel (RDF) constitution;
2) Electronics and composite packaging: Reverse Logistic systems enhancement and increase of fix points for collection of these materials open to population;
3) Rejects category: environmental education;
4) Glasses: since the economical feasibly is low in the past years, the reverse logistics and a facilitate way to economize in the transportation and direct access of the recycling industries to the used glasses.

Revista Gestão & Sustentabilidade
ISSN 2596-142X

4 Conclusions

This paper presented the gravimetric characterization of the selective household MSW sent to a manual sorting plant located in the central area of the São Paulo City, aiming to assess the real rejects that are going to sanitary landfill after sorting process. The results show that the sampling method was sufficient to be compared with other similar surveys in Brazil, proposing that Coopere Sorting Plant works better than the average of the Brazilian plants, and local households separates their MSW better than others. In relation to recyclables sold, this study surveyed around 69 tons/month or 53 % of the input, reaching about 50.2 % of rejects in the output, since the other plants in Brazil generate around 30 to 43 % of rejects in the output, being the other materials possible to be recycled, but do not.

The gravimetric composition of the MSW destined for the local household selective collection in Coopere Sorting Plant consists of: Plastics (29.2 %), Papers (27.1 %), Tetra Pak (7.3 %), Metals (7.3 %), Glasses (12.2 %), Styrofoam (1.7 %), Electronics (0.1 %), Composite Packaging (1.4 %) and Rejects (13.8 %). Besides, the gravimetric composition after the sorting process consists of: Rejects (50.2 %), Plastics (18.9 %), Papers (11.3 %), Tetra Pak (1.0 %), Metals (0.7 %), Glasses (0.7 %), Styrofoam (3.2 %), Electronics (0.2 %) and Composite Packaging (13.9 %).

The percentage of some specific types of plastic (PVC, LDPE, PP, PS, Others and unidentified) and Styrofoam raise the hypothesis that, although recyclable, not all materials are economically feasible to be recycled. In addition, pickers may find it difficult to identify in which category that polymer fits because of the lack of identification is fewer usual packages.

The calculation of the MRY made possible the analyses what is sold and what is not by the Cooperative, what can be reproduced by other similar studies, involving technological and economical solutions for waste like Styrofoam, unidentified plastics, composite packaging, and electronics. The analysis also contributed to give practical suggestions for each type of waste found in selective collection to a specific destination for waste to energy and recycling treatments, since developing countries like Brazil lack of faster and more effective public, social and environmental investments, involving environmental education campaigns and increasing of the door-to-door selective collection and logistic reverse systems.

The comparison with the local MRFs results shows that the selective collection program management needs to be improved in the whole city (only 2.4 % of the total MSW

Revista Gestão & Sustentabilidade
ISSN 2596-142X

generated in the study period, 2016-2017), including more trucks for door-to-door collection and environmental education. This is only possible through a work of raising public awareness about the importance of selective collection and of which materials can be recycled and treated. The importance of municipal management closer to plants is also perceived as a manner to training their sorting process, as well as the contribution of the packaging industries to supply and develop recycling technologies for their products, financially assisting the recycling industries and sorting plants.

5 Acknowledgements

The authors acknowledge FAPESP (São Paulo State Research Foundation), COOPERE and AMLURB (Municipal Authority of Urban Cleaning) to support this research.

References

ABRELPE. **Panorama dos Resíduos Sólidos no Brasil 2020**. São Paulo: Associação Brasileira de Empresas de Limpeza Pública e Resíduos Especiais, 2020.

ABREMA. **Panorama dos Resíduos Sólidos no Brasil 2023**. São Paulo: Associação Brasileira de Resíduos e Meio Ambiente, 2023.

BRASIL. **Lei Federal nº 12.305**, de 02 de agosto de 2010. Política Nacional de Resíduos Sólidos. Brasília, 2010. Available in: http://www.planalto.gov.br/ccivil_03/_ato2007-2010/2010/lei/l12305.htm. Accessed in: 22 October 2014.

ABNT. **NBR 10007: Amostragem de Resíduos Sólidos**. Associação Brasileira de Normas Técnicas, Rio de Janeiro, 2004, 21p.

ASTM D4687. **Standard Guide for General Planning of Waste Sampling**. American Society for Testing and Materials, Pensilvania, U.S.A. 2014 8p.

CEMPRE: **Pesquisa Ciclosoft 2018: Radiografando a coleta seletiva**. São Paulo: Compromisso Empresarial para Reciclagem, 2019.

FISCHER, C.; CROWE, M. **Household and municipal waste: comparability of data in EEA member countries**. Topic Report n. 3/2000. European Environment Agency, 2000, 69p.

GOTZ, R., BONDRIN, A., SCHEUTZ, C., ASTRUP, T.F. Physico-chemical characterization of material fractions in household waste: overview of data in literature. **Waste Management,** 49, p. 3-14, 2016.

IBGE. **Cidades: São Paulo – SP**. Instituto Brasileiro de Geografia e Estatística. 2020. Available in: https://cidades.ibge.gov.br/brasil/sp/sao-paulo/panorama. Accessed in: 07 December 2020.

JACINTO C. **Caracterização dos rejeitos provenientes da fração reciclável dos resíduos sólidos urbanos gerados pelo agrupamento sudeste do município de São Paulo-SP**.

Revista Gestão & Sustentabilidade
ISSN 2596-142X

Dissertação (Mestrado em Ciência e Tecnologia Ambiental) – Universidade Federal do ABC, Santo André, 2019, 132p.

JACOBI, P.R., BESEN, G.R. **Gestão de resíduos sólidos em São Paulo: desafios da sustentabilidade. Estudos Avançados**, São Paulo, 2011, p. 135-158.

MOREIRA, A. M. M. **Riscos e agravos à saúde do trabalhador em centrais de triagem de materiais recicláveis.** Tese de doutorado do Programa de Saúde Pública. Universidade de São Paulo, 2017.

MOURA, J. M. B. M., PINHEIRO, I. G., CARMO, J. L. Gravimetric composition of the rejects coming from the segregation process of the municipal recyclable wastes. **Waste Management**, 2018, 74, pp. 98-109.

OLIVEIRA M. A. **Proposta de amostragem e caracterização dos RSU secos recebidos e processados pela Central Mecanizada de Triagem Ponte Pequena, São Paulo-SP**. Dissertação (Mestrado em Ciência e Tecnologia Ambiental) – Universidade Federal do ABC, Santo André, 2019, 141p.

PASCHOALIN FILHO, J.A., SILVEIRA, F.F., LUZ, E.G., OLIVEIRA, R.B.: Comparação entre as massas de resíduos sólidos urbanos coletadas na cidade de São Paulo por meio de coleta seletiva e domiciliar. **Revista de Gestão Ambiental e Sustentabilidade** 3 (3), p.19-33, 2014.

PMSP. **Plano de Gestão Integrada de Resíduos Sólidos na Cidade de São Paulo.** Prefeitura do Município de São Paulo. 2014a. Available in: http://www.prefeitura.sp.gov.br/cidade/secretarias/upload/servicos/arquivos/PGIRS-2014.pdf. Accessed in: 15 April 2024.

PMSP. **AMLURB: Aterros e Transbordos**. Prefeitura do Município de São Paulo. 2014b. Available in: https://www.prefeitura.sp.gov.br/cidade/secretarias/subprefeituras/amlurb/aterros_e_transbordos/index.php?p=4633. Accessed in: 23 September 2018.

PMSP: **A dinâmica do IDH-M e suas dimensões entre 2000 e 2010 no município de São Paulo.** Informes Urbanos, n. 19, novembro de 2017. Prefeitura do Município de São Paulo. Available in: https://www.prefeitura.sp.gov.br/cidade/secretarias/upload/Informes_Urbanos/29_Dimensoes_IDH-M.pdf . Accessed in: 15 April 2024.

PMSP. **Subprefeituras.** Prefeitura do Município de São Paulo. 2019. Available in: https://www.prefeitura.sp.gov.br/cidade/secretarias/subprefeituras/amlurb/coleta_seletiva/index.php?p=4623 (2019). Accessed in: 14 March 2019.

PMSP: **Quantitativos – Resíduos coletados no município**. Prefeitura do Município de São Paulo. 2020. https://www.prefeitura.sp.gov.br/cidade/secretarias/subprefeituras/amlurb/index.php?p=185375 . Accessed in: 09 March 2020.

SAHIMAA, O., HUPPONEN, M., HORTTANAINEN, M. Method for residual household waste composition studies. **Waste Managemen**t, 46, p. 3-14, 2015.

SEMASA. **Caracterização gravimétrica e morfológica dos resíduos sólidos urbanos domiciliares do município de Santo André ano base 2017**. ORIUM Soluções Ambientais. Serviço Municipal de Saneamento Ambiental de Santo André, Santo André, 2018.

Revista Gestão & Sustentabilidade
ISSN 2596-142X

ONU. **The World´s Cities in 2018 – Data Booklet** (ST/ESA/SER.A/417). Department of Economic and Social Affairs, Population Division. United Nations. 2019. http://www.un.org/en/events/citiesday/assets/pdf/the_worlds_cities_in_2018_data_booklet.pdf (2019). Accessed in: 11 March 2019.