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COPPE UFRJ
Instituto Alberto Luiz Coimbra de Pós-Graduação e Pesquisa de Engenharia

PRELIMINARY DIAGNOSIS OF SOLID WASTE MANAGEMENT IN THE CITY OF RIO DE JANEIRO

2015

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Preliminary Diagnosis of Solid Waste Management in the City of Rio de Janeiro

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PREFACE

The City of Rio de Janeiro has taken on the challenge of transforming the municipality into a benchmark of sustainable city and, accordingly, has been launching several actions aimed at reducing current adverse impacts, cutting on greenhouse gas emissions, promoting mobility and accessibility, securing the city's resilience, and offering better living conditions to its residents.

To this purpose, the City introduced in 2009 an innovative Policy on Sustainable Waste Management, which is already showing positive results. In 2010, the new Waste Treatment Center – CTR-Rio opened in Seropédica. In 2012, the Metropolitan Landfill of Jardim Gramacho was definitively closed, allowing for the recovery of landfill gas by the Refinery of Duque de Caxias as an alternative fuel source and cutting methane emissions into the atmosphere. Also, in 2009 a project for the Expansion of Selective Waste Collection was launched with support from the Brazilian Development Bank – BNDES, which includes the construction of six new Waste Sorting Centers – the first of which started operating in 2014 – and the training of waste scavengers, promoting their social inclusion and supporting the Recycling production chain.

Other initiatives launched in 2013 are: the I Conference on the Environment of the City of Rio de Janeiro, focused on waste management, with wide participation of the organized civil society and the scientific community; and the Zero Waste Program (Programa Lixo Zero), a campaign to raise awareness among residents of the importance of keeping the city clean. In such manner, Rio de Janeiro wants to become a model of successful waste management.

Also in 2013, the first Municipal Plan on Integrated Management of Solid Waste was launched, a joint effort of two Municipal Secretariats (Environment and Public Conservation and Services) and the Municipal Urban Cleaning Company – COMLURB. The plan establishes the goals and guidelines for the sustainable waste management in the city of Rio de Janeiro.

The Municipal Secretariat of City Works is using rubber from scrap tires in the asphalt mix for road projects around the city, and large construction projects by the municipality – especially those comprising the revitalization of the Port Area and the implementation of a BRT system – are reusing Civil Construction Waste. These are strong examples that illustrate the shift of the City administration towards sustainable practices.

In light of the magnitude of climate change impacts and the need to identify potential areas for action in the reduction and mitigation of Greenhouse Gases (GHGs), in 2011 the City of Rio de Janeiro set goals for emission cuts. The disposal of solid waste from various private and public segments releases gases that play a relevant role in overall GHG emissions. Therefore, this study – Preliminary Diagnosis of Solid Waste Management in the City of Rio de Janeiro – will serve as a guide to future updates in the Municipal Plan on Integrated Management of Solid Waste as well as to the GHG Inventory for the City.

CARLOS ALBERTO MUNIZ
Municipal Secretary of Environment of the City of Rio de Janeiro

This Preliminary Diagnosis focuses primarily on identifying the major sources of solid waste generation and their respective quantities within the municipality of Rio de Janeiro. Data on both the waste collected by municipal authorities and that generated by the private sector was included, independently of the different disposal methods adopted by each generator.

It is worth noting the uniqueness of such an endeavor. Particular emphasis is given to the diverse range of data sources employed as well as to the statistical methods adopted in the treatment of data.

Future editions of this diagnosis will build on the knowledge of the current status of solid waste management and its evolution, enabling not only the adoption of increasingly effective waste management measures in the City but also the monitoring of developments in waste disposal by virtue of new control measures, reverse logistics impacts, and changes in the population's behavior.

It is worth mentioning that the large volume of Civil Construction Waste (CCW) identified characterizes the revitalization process the city is going through.

CLÁUDIA FRÓES FERREIRA
Coordination of Solid Waste

1. INTRODUCTION

Cities in developing countries are now faced with the challenges imposed by the environmental agenda of the 21st century, such as adaptation to and mitigation of climate change, and yet, at the same time, they still struggle with issues inherited from the 19th century, such as the need to extend access to basic sanitation to the entire population. A positive synergy between the actions aimed at these two issues can be harnessed. In the case of the collection and disposal of municipal solid waste (MSW), as an example, financial resources made available by projects within the Clean Development Mechanism of the United Nations Framework Convention on Climate Change (UNFCC) contributed to the construction of sanitary landfills and waste-to-energy plants, which collect and combust biogas; they contributed to advance the environmentally sound disposal of waste, as well as allowed a reduction in greenhouse gas (GHG) emissions.

In order to identify opportunities such as these ones, the current status must be surveyed, and its causes must be assessed. In order to design and enforce climate change policies and mitigation actions, an inventory of GHG emissions constitutes a tool of the utmost importance. Rio de Janeiro was one of the leaders in producing a city-scale GHG inventory. In 2000, the City Government presented the emission inventory of the three main GHGs – namely, carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) – for Rio de Janeiro in 1990, 1996 and 1998. In 2010, an updated inventory was published including 2005 data, accompanied of Emission Scenarios and an Action Plan to mitigate the city's GHG emissions. In December 2013, with technical support from COPPE/UFRJ, as in previous years, the City launched its third inventory encompassing these three main GHG emissions for Rio de Janeiro, which totaled 22.6 million tonnes of carbon dioxide equivalent (Mt CO2e) in 2012. Of this total, 2.3 Mt CO2e (ROVERE et al., 2013) originated from the Waste sector, in particular from the disposal of municipal solid waste (1.6 Mt CO2e), household and commercial sewage (0.5 Mt CO2e), and industrial wastewaters (0.13 Mt CO2e).

It is therefore undeniable how important the availability of reliable information on the generation, collection, treatment, and final disposal of the city's waste is to the improvement of its GHG inventories. Furthermore, an environmentally sound management of waste demands the gathering of information on the sector's developments and a detailed assessment that points to its causes by means of a specific study.

As a result, the Secretariat of Environment of the City of Rio de Janeiro (SMAC) decided to innovate and carry out this Preliminary Diagnosis on Solid Waste Management.

With a view to ensure a participatory process, it was initially decided to approach waste Generators, Disposal Facilities and Transporters by requesting their voluntary participation in the collection of data. Considering that the method prescribed by the IPCC's Tier 2[1] – First Order Decay Model (2006) requires data on the landfills of solid waste over 10 years, information on the 2002-2012 interval were requested to the agents.

As participation rates were lower than desired, it was necessary to develop a methodology to deal with the results of this process, and to make estimates using the database thus obtained from the 2010-2014 interval in a responsible manner. It was also possible to obtain data for earlier periods from public and private institutions. In this way, the study's database comprises the period between 2002 and 2014.

This publication contains the results of this Preliminary Diagnosis, providing an overview of key sectors and pointing out their contribution to the generation of waste.

It therefore complies with the City's goal of launching a continuous process of assessing solid waste management by the Municipality of Rio de Janeiro and providing data that support innovative environmental management practices in this important field.

[1]This study employed the First Order Decay Method – FOD (Tier 2), which means that historical data on at least 10 years of waste disposal on the city landfills was employed, along with IPCC standard values for the other parameters necessary for the calculations. The adoption of the Tier 3 method instead would require data on the share of each waste type on total wet weight and the methane generation rate constant. However, this information is not available in the national methodology of inventories nor in the Brazilian literature.

2. DEFINITION OF THE RESEARCH SCOPE

In order to make possible the elaboration of the Preliminary Diagnostic of Solid Waste Management in the City of Rio de Janeiro, the SMAC had previously established in the project's Terms of Reference the different categories of waste to be adopted, which served as a guide for defining the intervention areas to be targeted by the research team. In addition to Industry, Civil Construction (CCW), Health Services (HSW), Household and Public, and Large Generators (LG)[2], the Communities and Recycling sectors were created for the purpose of this study.

The observed lack of systematic data in many of the institutional records examined, which would enable their validation, has brought to light the necessity of searching for alternative sources that would allow the segmentation of the listed sectors.

In this regard, the research demonstrated that in all sectors were found agents[3] pertaining to three different "dimensions": Generators, Transporters and Disposal Facilities – even though some of these agents fitted more than one dimension. Figure 1 shows the estimated ratio in which these three dimensions are found: many Generators, a number of Transporters and very few Disposal Facilities.

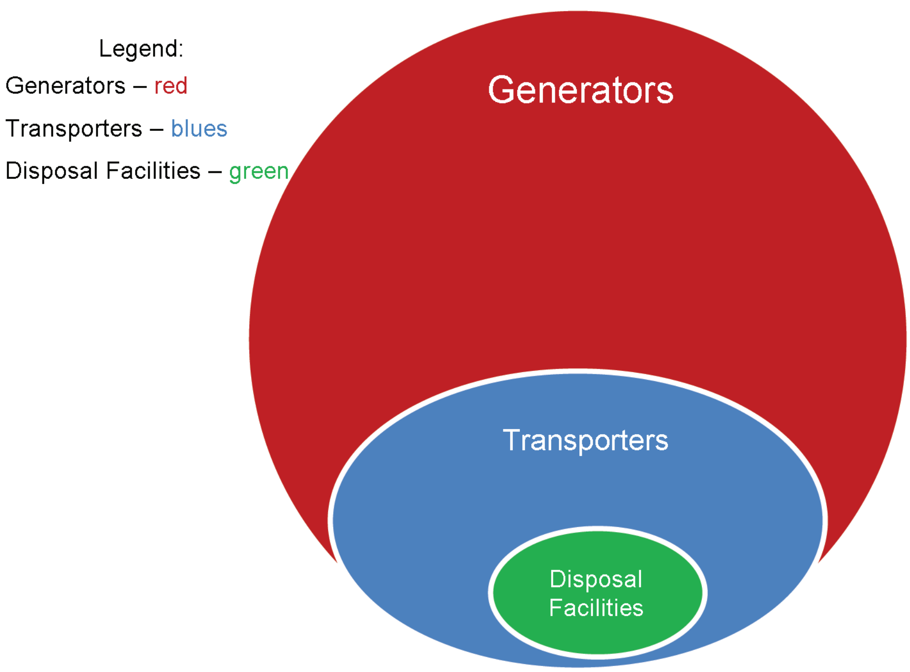

Figure 1 Estimated ratio between Disposal Facilities, Transporters and Generators

Source: Own elaboration.

[2]Large Generator – legal entity that generates over 120 liters or 60 kilograms of waste per day.
[3]Public or private institutions or individuals that generate, transport, or dispose solid waste.

If all waste generated were collected and appropriately disposed in its entirety, information obtained from the Disposal Facilities would suffice to establish the overall quantity of generated waste. However, in practice, not all waste is collected and, consequently, properly disposed, as shown in Figure 2 below:

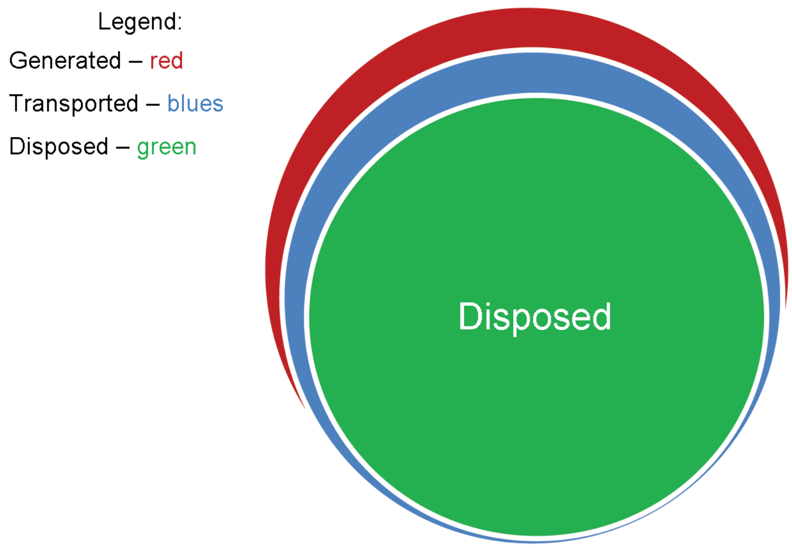

Figure 2 Estimated quantities of waste in each dimension

Source: Own elaboration.

As a result, the challenge in developing this Solid Waste Diagnosis was characterized by obtaining complete information from the Disposal Facilities dimension – since they presented both the smaller number of agents and the majority of data available on waste – as well as statistically sound information from the other two dimensions, so as to estimate the quantity of waste irregularly disposed.

It is worth highlighting that some Disposal Facilities are located outside the Municipality of Rio de Janeiro, and there is no way to ensure that all of them have indeed been identified. However, for the purposes of this study, the list of Disposal Facilities identified by the research team is assumed to comprise the whole universe of Disposal Facilities.

In the case of Generators directly served by the collection services of the Municipal Urban Cleaning Company – COMLURB, data by this institution on final disposal was adopted, as shown in Table 1 below.

Table 1. Data on Population and Solid Waste Collection in the City of Rio de Janeiro

Year	2005	2006	2007	2008	2009	2010	2011	2012
Population (inhabitants)	5,894,349	5,909,592	5,909,592	5,940,077	5,955,324	5,970,562	5,993,533	6,016,551
Household (t/day)	1,465,993	1,515,792	1,519,338	1,566,559	1,580,952	1,651,119	1,735,527	1,828,754
Selective Collection (t/day)	–	–	–	10,377	9,888	10,349	8,029	8,911
Public Waste (t/day)	1,141,511	1,186,458	1,236,926	1,201,834	1,131,753	1,178,805	1,147,624	1,174,326
Free Removal of Debris (t/day)	90,575	99,504	78,851	126,467	112,853	140,393	102,581	91,292
Civil Construction (t/day)	–	–	234,881	740,558	555,686	653,170	489,391	321,100
Other (t/day)	3,071,669	3,415,883	3,439,292	4,026,931	3,753,809	4,064,734	3,954,190	4,075,044
Other = Waste from Public, Industrial, and Private agents; Demolition Sites; Snails; Tires; Medical Waste; Large Generators; Tree Trimming; and Emergencies. Includes waste from Large Generators, Industrial Plants and Demolitions received at COMLURB's transfer and destination units.								

Source: COMLURB, 2013

As seen in lines 2 and 4 of Table 1 above, over 70% of COMLURB's collected waste comes from generators within the "household" and "public" categories. However, the latest edition of the National Census (IBGE, 2010) states that COMLURB itself is unable to serve all Household Generators: waste from some 11,000 households located in Subnormal Areas[4] and other 4,500 in Normal Areas[5], equal to 2.6% and 0.6% of the universe respectively, are not collected by the Municipal Company. Besides, the same publication also informs that 5% of the waste generated by Communities is not collected. In order to assess the current levels of irregularities in waste disposal within Subnormal Areas, this study conducted a Primary Sample Survey. By the cross-check of the study results and data from COMLURB, it was possible to make an estimation of the amount of uncollected waste.

With regard to other sectors, the universes of each dimension were surveyed, as shown in Table 2 below, to serve as input for the statistical analysis of the primary research.

[4]Term adopted by IBGE to name Underserved Communities.

[5]This Preliminary Diagnosis did not encompass this particular universe, which amounts to 2,406,906 households.

Table 2. Universe of agents in each dimension of waste sectors

	Generator	Transporters	Disposal Facilities
Households in Communities*	427,920	1	1
Industry	832**	36	7
Health Services (RSS)	283	20	4
Civil Construction (RCC)	18***	228	17
Recycling****	39		47
Large Generators (LG)	547	36	7

Source: Own elaboration (2014).

* Number of households surveyed corresponding to 1,393,314 inhabitants, selected in the interest of pinpointing the share not served by COMLURB.

** Records by FIRJAN informed the existence of 1,018 industrial agents, but the primary research revealed a smaller number.

*** Large contractors, large construction projects such as Metrô Rio, Port Region Urban Development Company of Rio de Janeiro (CDURP), construction sites licensed by SMAC (1306 filed processes), and free collection provided by COMLURB.

**** In the Recycling sector, transportation activities are carried out by waste scavengers associations or Disposal Facilities, and the figure of a Transporter does not exist, as seen in the sectors.

Regarding the universe of **Communities**, the following characteristics were found: the Generators consist of total households (427,920)[6] present in existing communities in the municipality of Rio de Janeiro (source: Census 2010 IBGE); the only official waste Transporter is COMLURB; and the Disposal Site for waste coming from Communities is a company that provides services to COMLURB.

Within the universe of **Industrial Waste**, 1018 industrial units were identified--according to data by the Federation of Industries of the State of Rio de Janeiro – FIRJAN. However, during an early stage of the field research work, it was verified that some industries kept only administrative headquarters in the city of Rio de Janeiro while other no longer existed, which reduced the universe in question to 832 companies.

In the sector of **Health Services Waste** (RSS) it is worth noting that the dimension of generators includes public hospitals from the three government spheres – municipal, state and federal – as well as private hospitals and UPAs (Emergency Care Units). Due to the special nature of waste generated by this sector, the number of Disposal Facilities is the lowest of all sectors, totaling only four agents.

In the **Construction Waste Sector** (RCC) (RCC), the city of Rio de Janeiro is going through major urban and structural changes executed by large construction companies, which are regarded as Generating agents for the purposes of this work: SIG Engenharia, Odebrecht, OAS, Brookfield, Carvalho Hosken, Calper, MDL, Concal, RJ2, PDG, João Fortes Engenharia and Merk Group, besides MetrôRio and CDURP – Port Region Urban Development Company of Rio de Janeiro. All of the above run construction sites authorized by the SMAC and COMLURB's free debris collection program, totaling 16 agents. As for the universe of RCC Transporters, 228 companies were identified, according to COMLURB's register.

[6] Corresponding to 1,393,314 inhabitants.

In the case of the **Recycling** universe, it is worth clarifying that Generators and Transporters overlap, due to the very nature of their work. They comprise for the most part Associations of Waste Scavengers with varying degrees of formalization, but all fully engaged in responding the questionnaires. Disposal Facilities, for total lack of responses, were not assessed.

Concerning the **Large Generators** (GG) sector, the challenge consisted of obtaining data from the major contributors, namely supermarkets, hotels and shopping malls. Information on Transporters and Disposal Facilities were not taken into account.

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3. ESTIMATION METHOD

This study applied the methodology known as "Methods for Finite Population Sampling" (COCHRAN, 1977; BOLFARINE and BUSSAB, 2005).

The purpose of finite population sampling techniques is obtaining information on populations characterized by N "elementary units" (people, objects, households, businesses, etc.). Each elementary unit is associated with one or more variables of interest, each one represented by a measurable value Y_i, i = 1, 2,..., N. The Yi values may correspond to inherently quantitative variables (weight, price, height, income, spending, etc.) or inherently qualitative ones (the units either have or not a given property, commonly represented by $Y_i = 1$ if positive, and $Y_i = 0$ if negative). In the first case, the most common situation is summarizing the population through a measure of central tendency (mean $Y_{med} = \Sigma Y_i / N$) and a measure of variability (variance $\sigma^2 = \Sigma (Y_i - Y_{med})^2 / (N - 1)$). Where a qualitative variable is used, Y_{med} = P = probability of a randomly selected elementary unit having the aforementioned property.

This information can be obtained from a census in which all the elementary units are recorded, allowing for the calculation of Y_{med} e σ^2.

This solution may be uneconomical when N is too large, which requires the use of a "sample", characterized by the selection of a number *n* of elementary units, followed by the calculation of "estimates" of the mean and variability – y_{med} = estimator of Y_{med}, and s^2 = estimator of σ^2. To ensure that these estimators are indeed representative, it is crucial that the selection method of the sample elements is well defined and conform to "random sampling" rules, in which the selection probabilities of each elementary unit are known. The values for y_{med} and s^2 (mean and variance of the sample) so obtained allow to determine the estimator $\hat{Y}$ of total *Y* and its standard deviation $SD(\hat{Y})$ = square of the variance of the estimator $\hat{Y}$, which in turn lead to a confidence interval for the unknown value *Y*. It is usual to set limits to the "coefficient of variation" $CV = SD(\hat{Y}) / \hat{Y}$ which consists of a relative measure of the estimate precision, as to ensure that the confidence interval is small in comparison to the total estimate.

Once the estimator $\hat{Y}$, standard deviation *SD*, and the coefficient of variance *CV* are obtained, it is then possible to obtain the values of these variables for the total *Y*. The Total Estimator of the Assessment will be the sum of all total estimators for each sector. The Total Estimator Standard Deviation of the Assessment is calculated as the square root of the sum of the variances of all sectors, which happens to be the square of their respective standard deviations. The Total CV is calculated by dividing the Assessment's Total Estimator SD by the Assessment's Total Estimator.

It is usual to consider studies as having acceptable precision if their coefficient of variation (standard deviation of total estimator/total estimator) is equal to or less than 10%. Therefore, it was established for this study that where the value of Total **CV is less than or equal to 10%, the data is deemed to be accurate enough**.

The CV is defined as the ratio *(standard deviation) / (mean)* of a random variable. Therefore, it measures the level of variability. If the random variable is the estimator of a given parameter, then the CV consists of a measure of the accuracy of this estimator. By establishing that a CV value of up to 10% is regarded as acceptable, it means that the estimator, in this light, can be considered satisfactory for the desired applications. The smaller the CV, the better the accuracy achieved. However, it must be considered that, in order to obtain small CV values, more resources are required to the estimation process. It is therefore customary to set a limit to CV value, which is related to the benefit-cost ratio of the field research work.

In addition, we consider the application of the **margin of the confidence interval**, which is just another way of evaluating whether precision is sufficient or not. The margin of the confidence interval is expressed as a percentage of the central value and is equal to ***k*** **times** ***CV*****, where** ***k*** **=** ***1.65*** **for a 90% confidence level and** ***k*** **=** ***1.96*** **for 95% confidence level**. These values are found on the table of standard normal distribution. It means that the actual value of total *Y* falls within this range with a probability of 90% or 95%, respectively. In this way, the more certainty is desired in achieving the real value of *Y* located within the confidence interval, the greater the margin should be. That is to say, to a certain degree the confidence interval and the estimator *CV* correspond to the same concept of estimation accuracy. The confidence interval provides information that is more complete because it implicitly weighs the benefit-cost ratio of the estimator. **The margin at 90% confidence level was regarded as adequate for the purposes of this study**.

The simplest example of the use of sampling techniques is a selection by “simple sampling without replacement”, in which individual units are selected by a lottery mechanism that assigns the same probability of selection to all elementary units, and after each draw excludes from the sample the basic units selected in the previous stages of the draw. For the rigorous use of this “Sampling Plan”, one needs to have access to a register of the elementary units.

Other sampling techniques commonly used are:

- stratified sampling – the population is divided into “strata” or sub-populations with less internal variability, and simple sampling is applied within each stratum in order to reduce uncertainty for the same sample size;
- cluster sampling – the population is divided into N_1 “clusters”, from which is selected a sample of n_1, with selection probabilities proportional to the size, with replacement, and simple sampling carried out within each selected cluster.

A **Sampling Plan** comprises the description of the sampling technique used: number *n* of elementary units to be selected; the selection probabilities assigned to the various elementary units: details of the selection method; and criteria adopted for the treatment of “non-responders”, that is to say selected elementary units of which no information could be obtained.

On the other hand, a **Census** is a type of sampling plan under which all the proposed universes are investigated. Its application occurs when the population is small enough to the point that the sample presents no significant difference from the universe, or when it is indispensable to count the entire population.

It was also found that the correlation between the historical quantities of waste production by each sector – following the aggregation established by Soares (2011) and COMLURB (2012) – and the Gross Domestic Product (GDP) per capita (IPP, 2014) allows the estimation of the waste quantities that will be produced in the coming years. The equations extracted from Report 3 of this project are presented in Table 3 below and expressed in tons per day:

Table 3. Equations for the Projection of Solid Waste Generation per Sector

Generator	Equation
Household	0.0373GDP per capita + 3,366.60
Public Sector	0.013GDPper capita + 2,885.10
Health Services (HSW)	- 0.0003GDPper capita + 44.84
Large Generators (LG)	- 0.0034GDPper capita + 915.69
Others	- 0.0279GDP per capita + 893.02

4. SAMPLING APPROACH

Because of the novelty of the research work and the diversity of data sources employed, and in the interest of quality assurance, it was initially decided to conduct a **Census of Disposal Facilities in all sectors**, since they represent a significant amount of the waste generated in the city as well as the group with the smaller number of agents. However, in some cases this was not possible, mainly due to lack of responses. In CCW, where 4 of the 14 Disposal Facilities did not answer the questionnaires, it was possible to adopt **simple sampling**, while in the HSW and LG sectors, from which no response was received, Disposal Facilities were not even considered.

Since not all the waste generated is collected and properly disposed of, the primary research in the various dimensions aims to identify this gap; therefore, a survey will be conducted by the means of a **Sampling Plan for Generators and Transporters**.

The sampling plans presented in this project (Table 4) are the result of established statistical criteria as listed below:

A) Determination of sample size admitting simple sampling

- Each combination (Occupation, Source) is treated as a universe of interest.
- For each universe of interest, it is determined the necessary sample size (n) to guarantee a margin of 5% of the interval at 95% confidence for a fraction P of the sample units that satisfy a given property, considering the "worst case", P = 50%;
- When the value of "n" is close to the one of N (number of units in the universe), a census is conducted;
- When n<N, the sample is selected by simple random sampling, without replacement – N random numbers are generated using the random function of MS Excel; each one is associated to the elements of the universe, which are then rearranged by order of the random numbers; and the first n numbers are used. No subjective criterion is used in the selection.

B) Adjustments to obtain greater precision and/or for reduction of costs

- Additional information is used to obtain greater precision (by stratified sampling) or reduction of cost per interview (by cluster sampling).

Table 4. Statistical Methods Applied in Each Category

Sector	Generator	Transporter
Communities	Divided in Large, Flat / Hillside Large: stratified sampling (10 chosen) Flat Terrain / Hillside (excluded from the “Large” group): cluster sampling in two stages, with probability proportional to size measured in number of households (15 in each group) Sample: 1100 households	Census
Industry	Stratified sampling Sample: 280	Census
HSW	Stratified sampling Sample: 152	Simple sampling
CCW[(1)]	Simple sampling Sample:10	Simple sampling
Recycling	Simple sampling Sample: Changeable sample according to the kind of waste, = 30 or 31 for most types. In the case of wood, only one company answered, making the estimation of the DP for this case impracticable.	Without Application
LG	Simple sampling Sample: 224 Sample (only malls, answers per type of waste): 14 respondents for organic waste and substantially fewer for the remaining types.	Census

Source: Own elaboration (2014).

[(1)]Disposal Facilities also surveyed by simple sampling and not by census.

In the Communities sector, questionnaires were applied directly by researchers at the households. In the remainder cases, the request was sent via e-mail and some visits were made to the universe; **the answers were considered as resulting from simple sampling, for the purpose of the analysis**.

After the primary research, the data of sampled sectors was assessed as to obtain their Coefficients of Variation; then, they were extrapolated using sectoral parameters; and, finally, they were employed in the validation of the process along with the surveyed data.

5. PRELIMINARY DIAGNOSIS OF SOLID WASTE MANAGEMENT IN THE CITY OF RIO DE JANEIRO

5.1 Waste from "Communities"

The data on Communities was supplied by the Pereira Passos Institute, being divided into three sub-universes – namely, long-established or large communities, communities located on hillsides, and those on flat terrain – as shown below in Table 4. The group encompassing "Large Communities"[7] was surveyed using the stratified sampling method, with sample sizes proportional to the communities' size measured in number of households, without replacement. The "Flat Terrain" and "Hillside"[8] community groups were surveyed using the cluster sampling method in two stages: 15 communities were selected for the first stage, with probabilities proportional to size, with replacement; the second stage covered 24 households, by simple sampling without replacement. Before the survey itself, a qualitative stage was carried out in two communities from each sub-group for the purpose of assessing the clarity of the questionnaire used and the respondents' engagement in supplying information, which served as a guide for subsequent investigation.

In this way, it was possible to collect data on the population habits regarding disposal of solid waste. The use of statistical techniques applied to the database obtained, according to the methodology presented in item 3, resulted in an estimate of total waste generated in the communities of the City Rio de Janeiro, totaling 603.94 t/day. The estimate is presented by group in Table 5 below.

Table 5. Estimators of Solid Waste and Respective Standard Deviations for the Communities Sector

Group	Total Number of Communities in the city	Number of Communities in the sample	Households	Sample (households surveyed)	Total Estimator (t/day)	Total Estimator SD (t/day)	VC (%)
Large	10	10	75,082	380	115.94	6.53	5.6%
Flat Terrain	568	14 *	191,409	360	247.81	27.77	11.21%
Hillside	448	13 **	161,429	360	240.20	20.30	8.45%
Total	**1,026**	**37**	**427,920**	**1,100**	**603.94**	**35.01**	**5.80%**

Source: Own elaboration (2014).

Obs.: The values originally obtained from the questionnaire are expressed in kg/month.

* There was one repetition in the sampling.

** There were two repetitions in the sampling.

[7] Ten communities chosen from the most populous, situated in different areas of the City; some located on hillsides, some on flat terrain; and some featuring Pacifying Police Units.

[8] The "Flat" and the "Hillside" groups comprise small, medium and large-sized communities, excluding the 10 communities selected in the Large category. Flat Terrain is defined as that with slope grade equal to or less to 10 degrees; Hillside present a slope greater than 10 degrees.

Table 5 shows that the resulting CV is less than 10%, and is therefore considered as good. In future surveys, it will be necessary to increase the number of questionnaires applied in order to reduce the Coefficient of Variation for Flat Terrain Communities and attain a value inferior to 10%.

Figure 3 shows the answers from Communities regarding regular and irregular waste disposal according to its destination, where regular disposal correspond to waste deposited in litter bins and dumpsters, and the remainder waste comprise the irregularly disposed waste.

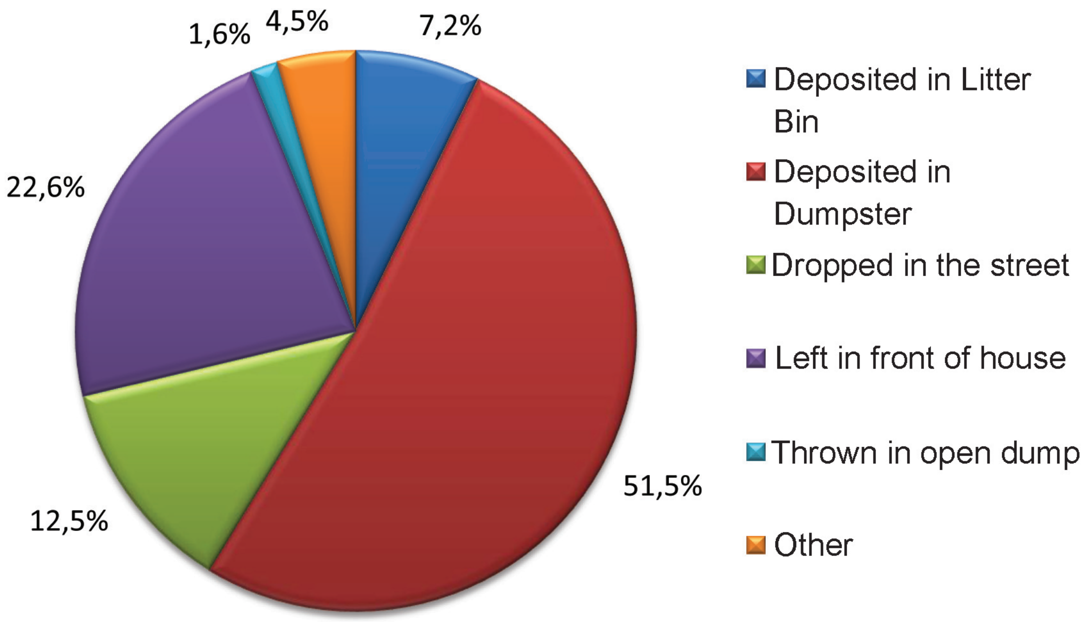

Figure 3 Destination of Solid Waste (%).

Source: Own elaboration (2014).

It was identified that, on average, 42% of household waste from communities is not properly disposed of. By applying this percentage to the total estimate, a total of 253.66 t/day of incorrectly discarded waste is obtained, with a proportional standard deviation of 14.71 t/day.

Because access to the communities is hampered by their often narrow and steep alleys, it is actually acceptable for waste not to be fully collected.

Despite COMLURB informing IBGE that 95% waste generated in Communities is collected – accounted for in the Municipal Company records under household and public waste – it was decided that for the purposes of this study the estimation of inappropriately disposed waste would be used as the actual contribution of the Communities sector.

5.2 Industrial Solid Waste and Wastewater

As detailed below, the estimated total quantity of industrial solid waste in the municipality of Rio de Janeiro totaled 413,500 t/year, or 1,133 t/day. Of this total, 12% are considered hazardous waste (Class I); 57% consist of non-hazardous, non-inert waste (Class IIA); some 31% are classified as non-hazardous, inert waste (Class IIB).

In this sector, estimated data for Industrial Wastewaters are included. As for solid waste, non-recyclable waste was included.

FIRJAN lists companies in its registry according to the number of employees (NE). Regarding the NE, the stratification shows that participation in the study from companies with the highest number of employees was also greater, as shown below in Table 6.

Table 6. Total Universe of Industrial Companies Divided into Two Strata

Number of Employees	Companies		Employed Persons in the sector	
	Total	Surveyed	Total	Surveyed
>30 (Cluster 1)	300	101	71997	46502
≤ 30 (Cluster 2)	532	26	6917	406

Source: Own elaboration.

Table 7 presents the overall estimated results of industrial waste and wastewater generation. This figure equals the sum of estimates for clusters 1 and 2.

Table 7. Estimates for industrial waste and wastewater in the municipality of Rio de Janeiro

Waste	(t/year)	(t/day)	%
Class I	49,278	135	12
Class IIA	237,463	650.2	57
Class IIB	126,902	347.7	31
Total	413,471	1,132.8	100
Wastewater	**m^3/year**	**m^3/day**	**%**
Wastewater	6,770,340.58	18,548.88	100

Source: Own elaboration (2014).

Industrial effluents, when suitable for treatment and treated effectively, generate industrial sludge and wastewater. Figure 4(a) shows the contribution of each industrial sector to the generation of industrial effluents and Figure 4(b) displays the types of waste treatment mentioned by industries in their answers to this study.

When treatment removes the danger of liquid effluents, they can be disposed of in the sewerage system. Otherwise, additional treatment is required.

As for the treatment of wastewater sludge, which is recorded as solid waste in Table 6 above, distribution by type can be seen in Figure 5, below.

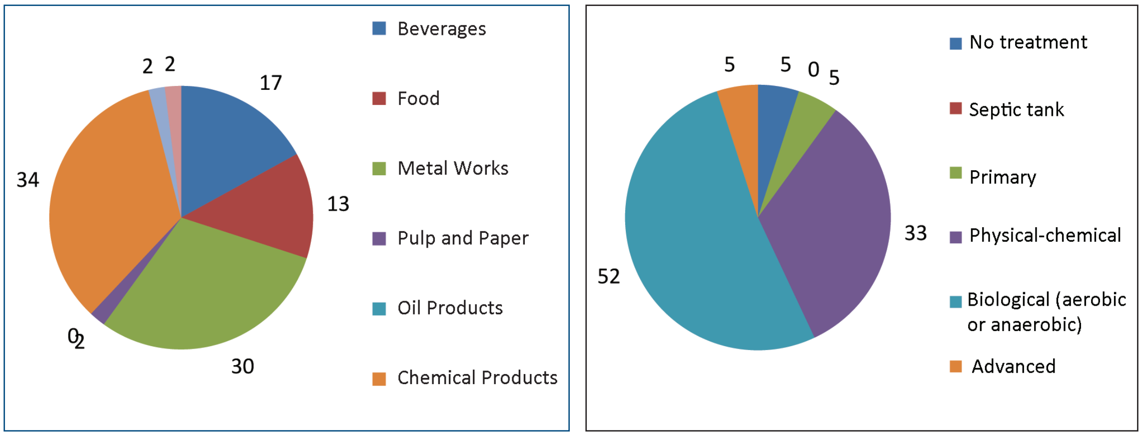

Figure 4 (a) Contribution (%) of effluents by type; and (b) Type of effluent treatment (%) adopted by surveyed companies.

Source: Own elaboration (2014).

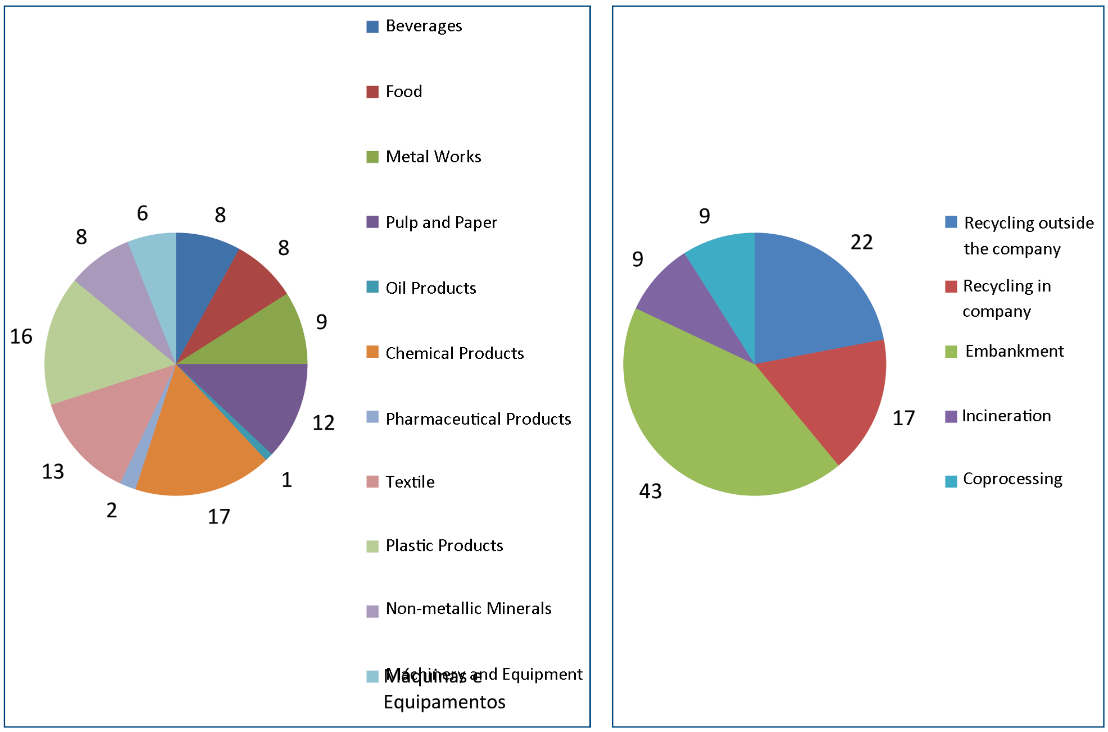

Figure 5 (a) Share (%) of industry sectors on industrial waste; (b) Type of solid waste treatment (%) adopted by surveyed plants.

Source: Own elaboration (2014).

5.3 Civil Construction Waste – CCW

The construction sector contributes a large share in the Brazilian Gross Domestic Product (GDP) and demands a large amount of non-renewable resources, mainly of mineral origin (Ferreira and Cardoso, 2013).

According to data provided by the Brazilian Association for the Recycling of Construction and Demolition Waste (ABRECON, 2013), construction and demolition debris account for 66.66% of total municipal solid waste in Brazil. Therefore, it plays a particularly significant role from the standpoint of logistics.

This impressive piece of data stresses the need for effective management of construction waste as to minimize its generation and increase reuse and recycling (Ferreira and Cardoso, 2013), thus preventing negative impacts on the useful life of waste disposal sites.

To carry out the diagnosis, all agents taking part in CCW management were surveyed: Generators, Transporters, and Disposal Facilities. The information obtained was integrated in a standardized system. It must be noted that the data provided on CCW encompasses all of its categories (A, B, C and D[9]). Also, the data obtained from the Municipal Secretariat of Urbanism is not restricted to demolitions and construction sites authorized the city government. Hence, it is considered that these values are also recorded in the data reported by Disposal Facilities.

[9]Class A waste, in accordance with CONAMA Resolution N. 307/2002, consists of reusable or recyclable waste such as that from:

a) pavement construction, demolition, renovation, and repairs, and other infrastructure works, including soil from earthworks;

b) building construction, demolition, renovation and repairs: ceramic components (bricks, blocks, roof tiles, surface slabs, etc.), mortar and concrete;

c) manufacturing and/or demolition processes of precast concrete parts (blocks, pipes, curbs, etc.) produced on construction sites.

Class B waste consists of recyclable waste for other applications, such as: plastic, paper, cardboard, metals, glass, wood, and plaster (as provided for in CONAMA Resolution n. 431/11).

Class C waste consists of waste for which no economically feasible technology or application has been developed allowing for its Recycling or recuperation; (as provided for in CONAMA Resolution n.431/11).

Class D waste consists of hazardous waste from the construction process, such as paints, solvents, oils and other, or contaminated/harmful arising from demolitions, renovations and repairs of radiology clinics, industrial facilities and others, as well as roof tiles and other objects and materials containing asbestos or other products harmful to humans (as provided for in CONAMA Resolution n. 348/04).

Table 8. Quantitative data on CCW supplied by Disposal Facilities

	Disposal Facility	Area (m²)	Employees	CCW (t/month)	CCW(t/day)
1	AMB&TECH	2,520	3	4.7	0.2
2	CHACO-VACO	14,000	60	4,000.0	133.3
3	CRR	52,540	462	100.0	3.3
4	CTR SEROPÉDICA	-	-	300.0	10.0
5	CTRCC	400,000	15	61,440.0	2,048.0
6	EMASA	200,000	20	36,354.0	1,211.8
7	CTR GERICINÓ	-	-	19,500.0	650.0
8	GLOBAL RCD	100,000	10	10,000.0	333.3
9	HAZTEC	-	429	790.7	26.4
10	PEDREIRA COPACABANA + ARCO DA ALIANCA	136,000	35	113,665.6	3,788.9
TOTAL		**905,060**	**1,034**	**246,155**	**8,205.2**

Source: Own elaboration (2014).

Selected by simple random sampling, 14 Disposal Facilities, 228 Transporters and 18 Generators of CCW were contacted. In tables 8 to 14, the respective quantitative data supplied by the companies and institutions that collaborated with this Diagnosis is presented.

The potential installed capacity of Disposal Facilities receiving CCW, which allows its reuse by third parties, amounts to approximately 4,700 t/day. However, it was not possible to precise the ratio of CCW that is actually returned to the construction production chain.

In the case of Disposal Facilities, respondents receive 8,205.2 t/day of CCW altogether, which amounts to 90% of the overall CCW generated in the city of Rio de Janeiro, according to the Association of Landfills for Construction Waste in the State of Rio de Janeiro (ASSAERJ). This group of companies was considered as stratum one; the remainder were grouped in the second stratum and the proportionality technique was applied, as shown in Table 9, below. This procedure allowed for a more precise estimation of overall CCW.

Table 9. Estimates of CCW Quantities from Disposal Facilities

Disposal Facilities	Quantty (t/month)		
	Stratum 1	Stratum 2	Total
Number of Companies	10	4	14
Representativity (%)	90	10	100
Total	246,155	27,357	273,506
Total SD	0 (census)	7,439	7,439
CV (%)	0	22.61	2.71

Source: Own elaboration (2014).

The figures were extrapolated to the universe and it is estimated that landfills receive **9,116** daily tons of solid waste, with a coefficient of variation (CV) of 2.26%, which is deemed as a very good level within the selected range.

Table 10. Quantitative data on CCW supplied by Transporters

	Transportador	Area (m²)	Employees	Fleet	CCW (t/month)	CCW (t/day)
1	Águia Entulho Transportes Ltda.	600	20	8	3,600	120.0
2	Alfa Ambiental	–	–	–	2,117	70.6
3	Big Entulho Ltda.	350	12	3	3,000	100.0
4	Cesar Transportes	12	6	4	354.17	11.8
5	França Entulho	–	1	1	190	6.3
6	Henri Log	50	47	16	37,440	1,248.0
7	J.D. Comércio e Transporte	600	25	–	2,521	84.0
8	Mastiga Entulho	100	3	1	80	2.7
9	Mega Entulho Ltda.	200	2	2	2,400	80.0
10	Paraíso Tobias Transporte e Serviços Ltda.	312	5	3	1,375	45.8
11	PC Serviços de Frete e Carreto Ltda.	250	2	1	180	6.0
12	Radar Transportes e Serviços de Engenharia Ltda.	320	6	3	2,400	80.0
13	Rainha do Sul Ltda.	400	4	2	1,620	54.0
14	Rio Entulho Ltda.	200	3	2	2,520	84.0
15	Sanetran	3,000	25	2	100	3.3
16	Seidel	20	2	3	73	2.4
17	Só Entulho Transporte Ltda.	420	4	19	4,200	140.0
18	Vale Suíço Transportes e Serviços Ltda.	350	3	3	300	10.0
19	VaptVupt Entulhos Ltda.	450	7	3	3,000	100.0
20	Vitor Hugo Demolições	91	125	–	–	–
21	WW Solução Rio Serviços Ltda.	200	3	3	270	9.0
	TOTAL	**7,925**	**305**	**79**	**67,740**	**2,258.0**

Source: Own elaboration (2014).

The 20 respondents from the Transporters dimension handle 2,258 t/day, an average 112.9 t/day per company; this group accounts for 8.7% of 228 companies in the sector. The estimation of transported quantities is shown in Table 11.

Table 11. Estimates of CCW quantities handled by Transporters

Transporters	Quantity (t/month)	Quantity (t/day)
Average per Transporter	3,387	112.9
SD	8,126	270.9
Average SD	1,625	54.2
Total	338,514	11,283.8
Total SD	162,514	5,417.1

Source: Own elaboration.

Extrapolating the figures of transported CCW, a total amount of **11,284 t/day** is obtained, presenting a coefficient of variation (CV) of 47.98% – which is considered bad, exceeding by far the acceptable threshold.

Table 12. Quantitative Data on Civil Construction Waste (CCW) from Large Generators (LG)[10]

	Generator	CCW (t/month)	CCW (t/day)
1	CGO-SMO	30,337.0	1,011.2
2	CITD	18,569.7	619.0
3	Free Removal by COMLURB	36.0	1.2
4	CONCAL	576.5	19.2
5	MERCK GROUP	1,606.0	53.5
6	METRÔ RIO	7,580.0	252.7
7	OAS	692.4	23.1
8	ODEBRECHT	3,984.0	132.8
9	SIG ENGENHARIA	4,638.6	154.6
10	OTHERS	4,365.4	145.5
11	OUTROS	66,525.1	2,217.5
TOTAL		**138,911**	**4,630.4**

Source: Own elaboration (2014).

Others = Renovation works authorized by the General Coordination of Urban Planning under the Municipal Secretariat of Urban Planning of Rio de Janeiro upon issuance of a certificate of occupancy.

The eleven Large Generators of CCW reported contributing 4,630.4 t/day, which corresponds to 420.9 t/day per Large Generator. Estimated totals are presented in Table 13 below.

Table 13. Estimates of Civil Construction Waste (CCW) by Generators

Generator	Quantity (t/month)	Quantity (t/day)
Average	12,628	420.9
SD	20,134	671.1
Average SD	3,786	126.2
Total	**227,308**	**7,576.9**
Total SD	**68,143**	**2,271.4**

Source: Own elaboration (2014).

The estimate obtained for Generators is 7,576.56 t/day, which equals the estimated universe of Generating companies contacted by the research team. This figure should be added to the contributions from renovation and construction works that require environmental licensing under SMAC Resolution 519/2012. Quantitative data on CCW generated by these works was obtained from the Technical Divisions of Regional Surveillance of the SMAC (GTRs). Since the available files date from 2004 to 2014, total generation by public and private entities within each source was calculated and then added up to obtain the monthly and daily average for the period.

[10]It was not possible to establish in this Preliminary Diagnosis the CCW quantities reused directly by ongoing major construction works in the City, either on the very construction sites or on other facilities of the generators. Only CDURP, the company in charge of the revitalization of the port area, informed its average daily waste recycling of 987.30 tons, which represents 98% recycling in 2014. It is important highlighting that other major projects, such as the BRT (Bus Rapid Transit), recorded approximately 1,267,300 tons of reused waste from the beginning of works (article published on O GLOBO – Rio section, Monday 15 Dec., 2014, p.6).

Table 14. Quantitative Data of Civil Construction Waste (CCW) from Generators registered on the Technical Divisions of Regional Surveillance (GTRs) of the Municipal Secretariat of Environment (SMAC)

	PUBLIC (t)				PRIVATE (t)			
	A	B	C	D	A	B	C	D
GTR1	110,467.49	11,442.78	1,623.98	69.22	2.069.603,90	83,107.37	15,316.30	1,723.79
GTR2	100,862.03	6,464.76	200.76	729.26	204.431,87	21,439.27	3,479.86	1,226.89
GTR3	276,751.76	17,361.02	1,551.74	1,134.81	2.160.084,31	84,770.35	11,701.06	2,442.65
GTR4	251,505.98	4,333.28	30.00	0.01	281.002,72	16,795.31	5,519.62	580.77
SUBTOTAL	**739,587.26**	**39,601.85**	**3,406.49**	**1,933.30**	**4.715.122,80**	**206,112.29**	**36,016.82**	**5,974.10**
TOTAL	**5,747,754.91**							
Monthly Average (2004-2014)		**6,163.23**						
Daily Average		**205.44**						

Source: Own elaboration (2014).

The sum of the daily average values of waste generated in large construction sites and those surveyed by the GTRs equals **7,782 t/day**. However, the coefficient of variation (CV) is quite high, reaching 29.98% and thus surpassing the desired range.

Based on the lowest coefficient of variation, of approximately 2.71% (9,116 ton/day), the value to be considered for CCW is the one obtained from the survey on Disposal Facilities.

5.4 Recycling Waste

In this work, the term Recycling names the sector that encompasses the separation, collection, sorting, and destination of waste by large wholesalers operating in the municipality of Rio de Janeiro, which includes the participation of scavengers of recyclable waste in some stages. Large wholesalers are responsible for handling, either directly or after processing, recyclables to industrial plants, which for the most part are located outside the municipality – and often outside the state – of Rio de Janeiro.

It is worth mentioning that CDURP has reported sending some 1,000 t/day of waste to recycling. However, since it was the only Generator to report this practice, it was not possible to estimate the potential recycling for all generators.

Figure 6 presents the generic flow of actions or processes by each agent necessary to the waste Recycling.

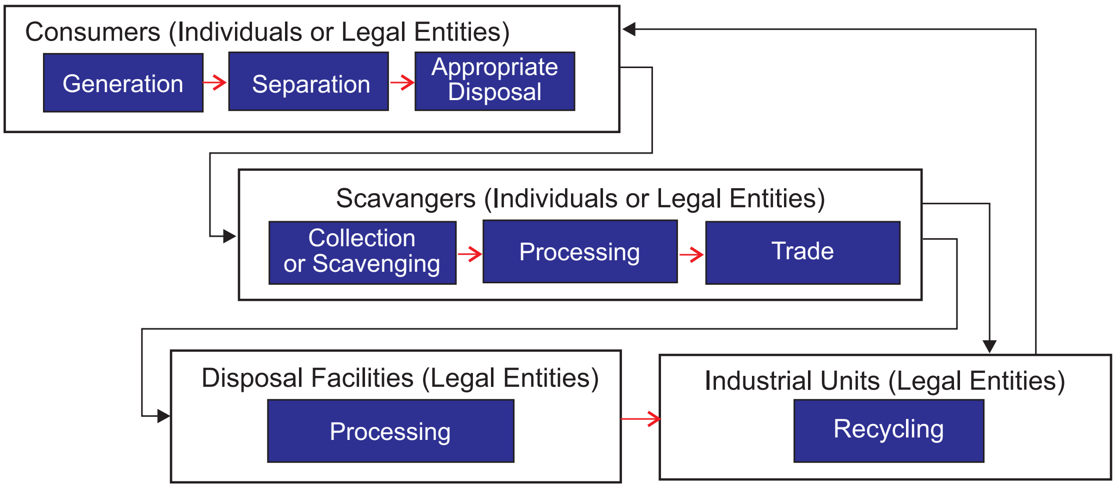

Figure 6 Flow of actions or processes by agent necessary to waste recycling

Source: Own elaboration (2014).

The model of diagnosis adopted by the recycling organizations[11], prepared by COMLURB in 2013 with the title Diagnostic Table of Cooperatives, was used with some adjustments in the field work applied during the elaboration of this Diagnosis. The research identified 39 currently operating organizations, of which only 31 keep records of processed quantities. The census[12] of waste scavengers' associations carried out by the field team is presented in Table 15.

Table 15. Quantities Informed by the 31 Recycling Organizations Identified and Contacted

Waste Type	Quantity (t/month)	Quantity (t/day)
PET	201.4	6.7
Rigid Plastic	156.3	5.2
Plastic Film	140.1	4.7
Glass	363.7	12.1
Iron	247	8.2
Aluminium	55.7	1.9
Copper	4	0.1
Metal	11	0.4
Paper	866	28.9
Cardboard	519.3	17.3
Tetrapak cartons	31.6	1.1
TOTAL	**2,596.1**	**86.6**

Source: Own elaboration (2014).

These entities recycle on average 2,596.1 tons of recyclable materials, especially paper, cardboard and glass each month. They also handle on average a monthly flow of 16,340 liters of used cooking oil and 96 tons of wood.

[11]It was chosen to name these entities 'recycling organizations', since in practice there are several different types of organizations – waste scavengers' cooperatives, associations, companies, and religious organizations – that perform recycling.

[12]Since a Census was carried out for this sector, there is no need to perform any validation test.

The field research among recycling organizations identified 47 Disposal facilities that receive their recyclables and are duly regularized with the National Register of Legal Entities. According to the Department of Applied Research[13] of COMLURB, the 47 Disposal Facilities concentrate their products in 4 or 5 companies (formal and informal), as also mentioned in COMLURB, 2014a[14]: *"... hundreds of small and medium private deposits of recyclable waste (about 600 "junkyards") and 4 or 5 large deposits that collect recyclables from these small and medium businesses (in addition to materials of residential blocks and condominiums and commercial property that separate and sell recyclables to deposits).*" However, these companies did not answer the study's questionnaire.

The analysis of potentially recyclable materials from the selective waste collection carried out by COMLURB in 30 districts presented a constant average distribution, shown in Figure 7.

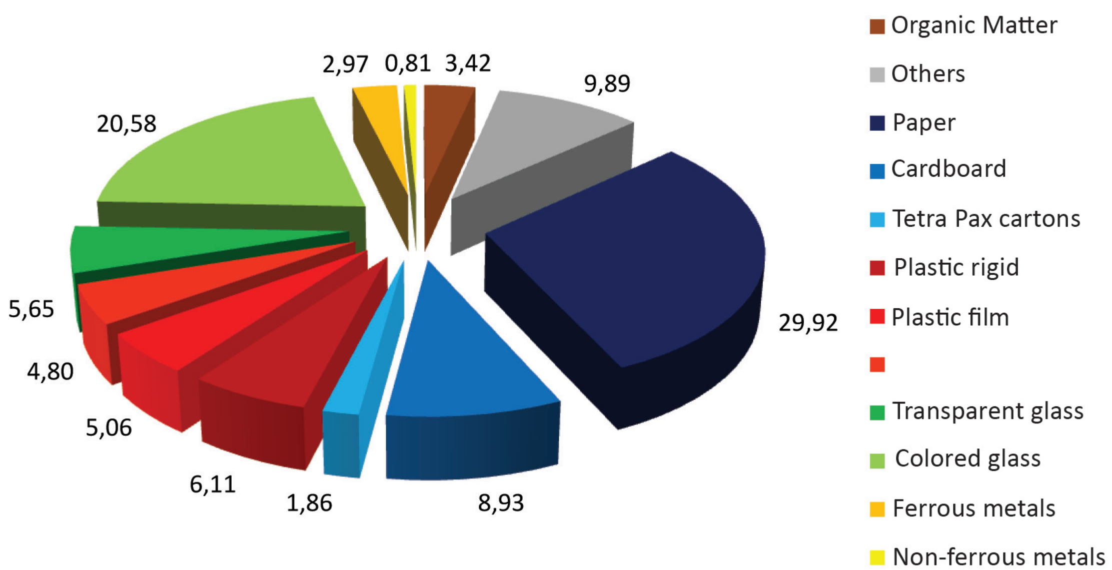

Figure 7 Potentially Recyclable Waste – average of Selective Waste Collection Samples from 30 Areas.

(please refer to the paragraph above mentioning "potentially recyclable materials", since the gravimetric analysis includes non-marketable recyclables)

Source: COMLURB, 2014.

Figure 7 shows that commercially recyclable waste is composed of three main components: paper and cardboard, glass, and plastics, which together added up to over 80% of total waste weight. The study also found that, in the 30 areas analyzed on December 2013, selective waste collection represented **0.87%** (1,372 tons) of the total collected domestic waste. It must be noted that COMLURB's selective collection still does not serve all the districts of the municipality; also, the population needs to be more aware of the issue of contamination of separated materials. It must also be made clear that the

[13]Interview conducted in March 2014.

[14]COMLURB: Selective Waste Collection: Characteristics of 30 areas of the City of Rio de Janeiro. Applied Research Department. Feb. 2014a.

collection process of recyclables generate losses that end up being collected again by COMLURB as urban waste.

In interviews conducted with agents and researchers from the segment, it was found that, in recent months, there has been a significant change in the recycling sector in the city of Rio de Janeiro. Some explanations for the latest improvements were provided by members of recycling associations and knowledgeable people in the industry:

- The expansion of selective waste collection by COMLURB, which by September 2013 had already reached 68 areas[15] of Rio de Janeiro.
- Increased delivery of recyclables by COMLURB to waste scavengers' associations.
- The destination of waste from large events (such as World Youth Day, Rock in Rio and FIFA World Cup) to recycling cooperatives.
- The increase in recyclable materials delivery to waste scavengers associations by public institutions, especially in the federal sphere.
- The practical outcomes of projects Cataforte[16] I and II.
- Training and operational support to scavengers associations, promoted by public and private agencies, although with low systematization, such as:
  - The workshops applied by the National Service of Cooperative Learning (SESCOOP) within the Program for Expansion of the City Selective Waste Collection (Agreement 10.2.2030.1, signed between the municipality and the BNDES in December 2009, of the Federation and Organization of Brazilian Cooperatives of the State of Rio de Janeiro – OCB/RJ).
  - The Information and Research on Waste Program at the Technical Solidarity Center (SOLTEC) of the Interdisciplinary Center for Social Development (NIDIS) of the Federal University of Rio de Janeiro.
  - The Technological Incubator of Popular Cooperatives (ITCP) of the Graduate School and Research in Engineering (COPPE), of the Federal University of Rio de Janeiro (UFRJ).
  - The Coca-Cola Institute in partnership with the NGO *Doe Seu Lixo* (Donate Your Trash).
  - The company Waste Wise and the Recicoleta/Tetra Pak, which provide training and tools for scavengers' associations.
- The growing number of companies, blocks and condominiums that already destine their recyclable waste, via sale or donation, directly to recycling entities.

[15]http://www.rio.rj.gov.br/web/comlurb/exibeconteudo?id=4380174 acesso em fevereiro 2014.

[16]Cataforte consists of a project aimed at supporting networks of cooperatives and associations, empowering them to provide selective collection services to municipalities, take part in reverse logistics activities, and jointly trade and process recyclable goods. Cataforte I started in 2009 with the main goal of fostering the organization of waste scavengers' groups based in the principles of solidary economy. Cataforte II began in 2010 and aimed at strengthening the logistics of scavengers' associations and cooperatives, by then already organized into networks. This second project provided trucks for recycling associations, which are shared by some scavengers' associations, enabling operation of collection and trade of materials.

- *The operations of Cooperativa de 2º Grau* (cooperative made up of 5 other cooperatives), such as the *Rede Recicla Rio* network.
- The operations of the 1st Sorting Center in Irajá, from the municipality -BNDES program COOP-FUTURO.

It should be noted that, because of the nature of the work, Generators and Disposal Facilities transport the materials themselves, eliminating the Transporter figure in this sector.

The data used is restricted to that obtained, by census, from Generators. The Disposal Facilities, for total lack of responses, were not assessed.

5.5 Health Services Waste – HSW

Based on questionnaires responses from Generators, it was possible to estimate that their production of Health Services Waste (RSS) at 124.7 t/day. The quantities informed by Transporters and Disposal Facilities consisted of 237.3 t/day and 20.8 t/day, respectively. However, this data was not considered in this diagnosis since these agents also handle materials from other municipalities.

The generators were divided into three first level strata: public hospitals, UPAs-Emergency Care Units, and private hospitals. Public hospitals were surveyed by stratified sampling (initial and supplementary[17]) with simple sampling within each stratum. For private hospitals, stratified sampling was also used, with a census carried out for first stratum and simple sampling for the second stratum. UPAs were surveyed by simple sampling.

Table 16 below shows the classification of HSW by group according to ANVISA (National Health Surveillance Agency).

Table 16. Groups according to ANVISA Resolution – RDC 306-2004.

Groups	Description
Group A	Waste with possible presence of pathogenic biological agents
Group B	Chemical Waste
Group C	Radioactive Waste
Group D	Waste akin to Household Waste
Group E	Sharps Waste

The quantity of Group B waste in virtually all the generators is close to 0%, that is to say, very small when compared to Groups A and E, which in turn are smaller than Group D. The latter consists to a large extent of organic waste generated by hospital restaurants and kitchens, and then collected and disposed of in landfills by different companies specialized in transport and treatment of medical waste. All hospitals failed to provide

[17]Initial mean the public hospitals that answered during the first stage. In the following stage, those who failed to responded were sampled with a smaller sample size, and those who responded were accounted for in the supplementary stratum. These two strata were treated separately, and then aggregated using stratified sampling methods.

data on the collection of radioactive waste (Group C), although it was covered by the questionnaire submitted. In a future edition, the CNEN – National Nuclear Energy Commission - which regulates the subject should be consulted, including on the transport of radioactive waste (CNEN-NE Standard 501, 1988).

To the purposes of this Diagnosis, HSW encompasses only the waste that requires special treatment and disposal, differently of those applied to MSW, and therefore consists of waste from Groups A, B and E above.

Data from COMLURB on the collection of medical waste from 2005 to 2011 was also taken in consideration, a period when the company was responsible for the collection, transportation and final disposal of medical waste. In the document “Gravimetric and Bacteriological Characterization of Household Solid Waste Collected by COMLURB in the city of Rio de Janeiro - 2012”, it is reported that 4,897 tons of HSW were collected in 2011, as seen in Table 17. The decreasing value over the years indicates an increasing efficiency in the separation of infectious from non-infectious waste in the source. This figure was recorded under the dimension of Disposal Facilities.

Table 17. Health Service Waste (HSW) Collection in the City of Rio de Janeiro

	2005	2006	2007	2008	2009	2010	2011
Population (inhabitants)	5,894,349	5,909,592	5,909,592	5,940,077	5,955,324	5,970,562	5,993,553
HSW Collection (t/year)	15,089	14,758	14,324	13,336	7,772	6,667	4,897
HSW Collection (t/day)	41.3	40.4	39.2	36.5	21.3	18.3	13.4

Source: COMLURB (2014a), IPP (2013).

Table 18 presents the validation tests and estimated generation by HSW Generators in the city of Rio de Janeiro.

Table 18. Validation Tests and Estimated Generation

Units	Surveyed Data (t/year)	N (units)	n (units)	Average (t/year)	Average Variation (t/year)	CV (%)	Estimador Total (t/ano)	Estimador Total (t/dia)
1. Generators	4,421.30	283				54.03%	45,514.9	124.7
1.1 Public Hospitals	2,484.50	76		90.49	1,823.95	47.19%	6,877.40	
1.1.1 Stratum 1 – Initial	2,250.00	8	8	281.25	0.00		2,250.00	
1.1.2 Stratum 2 – Supplementary	136.10	68	2	68.05	2,278.36		4,627.40	
1.2 UPAs	98.40	30	5	19.68	0.75	4.40%	590.40	
1.3 Private Hospitals	1,936.80	177		214.96	18,967.14	64.07%	38,047.1	
1.3.1 Stratum 1 – Rede D'Or	1,499.10	10	10	149.91	0.00		1,499.10	
1.3.2 Stratum 2 – Supplementary	437.70	167	2	218.85	21,306.66		36,547.95	

Source: Own elaboration (2014).

Obs.: “N” represents the number of elements in the Universe. “n” represents the number of elements in the sample. CV represents the Coefficient of Variation.

The CVs obtained for UPAs were considered good, while those of both Public and Private Hospitals were poor ones. The overall CV for the Health Sector can be considered as poor.

It must be noted that data from Transporters and Disposal Facilities were disregarded because they serve customers from other cities and do not segregate their data.

5.6 Household and Public Waste

5.6.1. Household and Public Effluents

According to the National System of Sanitation Information (SNIS) (Ministry of Cities, 2013), the State Water and Sewerage Company (CEDAE) and Foz Águas together collect 80.95% of the sewer generated by the households in the municipality of Rio De Janeiro, equivalent to 462,795,830 m^3/year, of which 400,101,000 m^3/year by CEDAE. Therefore, effluent data in the city have been requested to both institutions via questionnaires.

Treatment processes are applied to 332,189,480 m^3/year, of which 326,553,000 m^3/year by CEDAE (Ministry of Cities, 2013). From the data informed in the questionnaires, it was observed that in the most units secondary treatment is carried out, with activated sludge systems, and the amount of generated sludge reaches 4,253 tons per year (CEDAE and FOZ ÁGUAS, 2014). In all units, the destination of the sludge after treatment is the sanitary landfill.

5.6.2. Household and Public Waste

Urban solid waste comprise all the waste collected through the cleaning of streets and public parks, together with the waste collected by COMLURB from households and small Generators[18]. Thus, the data reported from COMLURB, who performs waste management in the City of Rio de Janeiro, has been considered in this Diagnosis.

On the basis of the gravimetrical analysis by COMLURB, due to the significant participation of the organic content in urban waste, its importance as methane emitting source has already been highlighted in the Greenhouse Gas Emissions Inventory for the City of Rio de Janeiro.

However, as the emission factors used in the inventories were taken from a table suggested by the United Nations, one of the main purposes of this Diagnosis is to identify the effective waste contribution in function of its characteristics. Therefore, the research work made use of an analysis of the macronutrient composition of collected waste in order to estimate methane generation according to the data from different areas of the City.

The mean income and (whenever it was possible to obtain waste samples) the contribution of organic matter by each city district have been taken into consideration. The cross-check of COMLURB data with that by IBGE (2010) – on the mean income of

[18]In accordance to Municipal Law n. 3,273, of 6 September 2001, paragraph IX, article 7, which defines the large generator, the Small Generator was determined as a Legal Entity generating up to 1 bag of 120 liters of waste per day.

the population of Rio de Janeiro—allowed the identification of Planning Area (PA) 2.1 as the one presenting the highest income, and PA 3.3 as the one with the lowest income[19].

The districts selected to represent each PA in this research are Lagoa (PA 2.1) (high income) and Manguinhos (PA 3.2) (even though it does not appear under PA 3.3, it was considered by IBGE as one of the lowest income districts in the city). For the purpose to analyze a medium income area, Tijuca (PA 2.2) was included in the selected districts. Table 19 below presents the average content found in all samples.

Table 19. Results of the Characterizations of the Organic Matter Samples

Income	Fruits, Vegetables and Rinds (%)	Leaves, Stems, Straw, Gram and Roots (%)	Food Leftovers (%)	Others (%)
High	62.85 (±0.45)	5.17 (±0.67)	16.61 (±2.47)	15.37 (±1.95)
Medium	71.19 (±3.39)	6.19 (±1.59)	9.34 (±2.84)	13.28 (±1.62)
Low	58.07 (±8.36)	5.02 (±1.33)	17.55 (±1.42)	19.36 (±5.62)
Overall	**64.04 (±7.31)**	**5.46 (±1.22)**	**14.50 (±4.38)**	**16.01 (±4.08)**

Source: Own elaboration (2014).

The results of the analysis of household waste represented by the samples selected in this study (high, mean and low income) underwent statistical analysis by means of the SPSS Statistics version 22 software, for use of Analysis of Variance Tests (ANOVA), including Post Hoc Tests (Tukey, T3 Dunnet). There are not significant statistical differences among the samples of high, mean and low income.

The samples of the listed districts were submitted to physicochemical and macromolecular composition analyses, which outcomes are described in Table 20, and were used to quantify the contribution of organic waste to greenhouse gas emissions.

Table 20. Average Values of the Physicochemical and Macromolecular Composition Analysis for the High, Medium and Low Income Samples

Income	Wet waste (%)	Solid Volatile Waste (%)
High	77.34 (±1.26)	92.64 (±3.35)
Medium	79.55 (±1.11)	90.93 (±1.28)
Low	72.30 (±1.04)	90.91 (±2.27)
Overall	**76.40 (±3.37)**	**91.49 (±2.29)**

Source: Own elaboration (2014).

According to Ehrig (1991), the theoretical generation of CH_4 is 453 NmL of CH_4/g of carbohydrate, 509 NmL of CH_4/g of protein and 1,021 NmL of CH4/g of lipid. These values were multiplied by the amounts found in the laboratory tests, providing the data presented in Table 21 below.

[19]Although PA 3.3 present the lowest income in Rio de Janeiro, COMLURB had no data available on the area. The Planning Area with the lowest income and availability of data by COMLURB is PA 3.2. As a result, the work was conducted using PA 3.2.

Table 21. Theoretical Potential of Biogas Generation by Stoichiometry for the High, Medium and Low Income Samples

Income	Chemical characterization (% weight)			Theoretical Potential of CH_4 (NmL/g or Nm³/ton)*
	Carbohydrates	Proteins	Lipids	
High	22.5	68.8	8.5	538.9
Mean	37.3	56.5	6.1	518.8
Low	51.0	39.0	9.4	525.5
General	36.9	54.7	8.0	527.7

Source: Own elaboration (2014).

*Cumulative Biogas Volume (ml or m³) corrected for the Standard Conditions of Temperature and Pressure – SCTP.

According to Table 20, the theoretical potential yield of CH_4 varied from 518.8 to 538.9 m³/ton of organic waste, with highest values found in high income samples, probably due to their higher content of protein, which contribution to methane generation is greater than the carbohydrates one.

It is important to point out that values provided solely by theoretical gas yield equations can be high, since these formulas assume optimal conditions of waste anaerobic degradation (Maciel, 2009). Many factors can influence the decomposition process, thereby reducing potential biogas generation, which only stresses the importance of parallel experimental studies to obtain more accurate data.

These studies will make possible an adequate assessment of the potential of biogas generation from waste in the city, including posterior energy use.

5.7 Residues of Large Generators

For the sector of Large Generators, the data encompass waste disposed at landfills excluded from their recyclable content.

Large Generators consist of agents that generate more than 120 liters or 60 kilograms of waste per day and that are not addressed by other sections of this Diagnosis. They were divided into three groups, namely Shopping Malls, Supermarkets, and Hotels, each analyzed by random sampling. Street restaurants and stores were not taken in consideration, even those exceeding the 120 daily waste liters threshold.

Table 22 shows the data obtained from three corporate groups who together own 16 shopping malls, whose detailed information are included in Report 5 of the Preliminary Diagnosis of Solid Waste Management in the City of Rio de Janeiro.

Table 22. Results of the Primary Research on the Malls sub-sector

Corporate Group	Gravimetric Composition (t/year)								
	Organic	Paper and Cardboard	Aluminum	Iron	Steel	Metal	Plastic	Glass	Batteries
Ancar	4,117.5	96.6	25.7	64.3	4.2	0.1	0.5	0.6	0
BR Malls	4,000.9								
Multiplan	4,824.5	660.0	567.4	10.9	0	0	19.4	0.1	0.3
Total	**12,943.0**	**756.5**	**593.2**	**75.2**	**4.1**	**0.1**	**19.9**	**0.7**	**0.3**

Source: Own elaboration (2014).

It is worth mentioning that not only did the BR Malls group provide data only on organic waste generation, but also two of its eight shopping malls did not return their questionnaires. All five malls from the Ancar group as well as Multiplan's three malls provided data on some of the remainder categories of waste.

Table 23 below presents the data validation (the Coefficient of Variation) for the 16 shopping malls in the sample and their extrapolation (Total Estimator) to the universe of the sector, which consists of 37 shopping malls altogether (ABRASCE, 2014).

Table 23. Validation of the Primary Research on the Malls sub-sector

Material	N (population)	n (sample)	Average Estimator (t/year)	SD Estimator (t/year)	Total Estimator (t/year)	SD of Total Estimator (t/year)	Coefficient of Variation
Organic	37	14	924.50	1,218.62	34,206	9,500.97	27.78%
Cardboard	37	2	41.80	33.65	1,546	856.34	55.37%
Mixed Paper	37	3	224.31	305.00	8,299	6,245.67	75.25%
Aluminium	37	6	98.86	199.15	3,658	2,753.53	75.28%
Iron	37	5	15.05	26.74	557	411.51	73.92%
Steel	37	2	2.06	2.84	76	72.37	94.99%
Metal	37	1	0.07	NA	3	-	0.00%
Plastic	37	3	6.62	8.70	245	178.15	72.70%
Glass	37	3	0.24	0.34	9	7.00	77.69%
Batteries	37	2	0.12	0.17	4	4.30	96.53%
Total (t/year)					**48,604**	**11,738.76**	**24.15%**
Total (t/day)					**133.2**	**32.2**	**24.15%**

Source: Own elaboration (2014).

The total figure was obtained by the sum of total estimators for each material type. Therefore, the total estimated quantity of waste generated by Shopping Malls is 133.2 t/day, with a standard deviation of 32.2 t/day. The CV thus obtained (24.15%) is considered poor according to the criteria established for this work.

The Hotels subsector contributed with little data for the research. Therefore, Tables 24 and 25 show, respectively, the waste generation by a single agent – Copacabana Palace Hotel – and the average occupancy rate of hotels in the municipality of Rio de Janeiro.

Table 24. Records of Special Waste Collection of the Copacabana Palace Hotel

Month	Number of 240 l containers	In m³	In liters	Number of monthly guests	In liters per guest
jan/09	1349	324	323760	7758	42
fev/09	1299	312	311760	7161	44
mar/09	1478	355	354720	6938	51
abr/09	1390	334	333600	6991	48
mai/09	1408	338	337920	5414	62
jun/09	1140	274	273600	4839	57
jul/09	1274	306	305760	5420	56
ago/09	796	191	191040	6572	29
set/09	635	152	152400	6123	25
out/09	863	159	159120	7914	20
nov/09	596	143	143040	8003	18

Month	Number of 240 l containers	In m³	In liters	Number of monthly guests	In liters per guest
dez/09	733	175	175920	9444	19
jan/10	672	161	161290	9883	16
fev/10	675	162	162000	8541	19
mar/10	680	163	163200	9435	17
abr/10	651	156	156240	8238	19
mai/10	735	176	176400	6621	27
jun/10	633	152	151920	4922	31
jul/10	655	157	157200	5809	27
ago/10	630	151	151200	6472	23
set/10	667	160	160080	6259	26
Average waste generation per guest without waste management (in liters)					**51**
Average waste generation per guest with waste management (in liters)					**23**

Source: Copacabana Palace Hotel (2014).

Table 25. Average hotel occupancy rate in the city of Rio de Janeiro

Year	Occupancy rate
2000	69.96%
2001	66.60%
2002	61.71%
2003	60.90%
2004	61.75%
2005	59.65%
2006	63.06%
2007	62.98%
2008	65.86%
2009	68.79%
2010	73.75%
2011	79.08%
2012	76.95%
2013	71.86%

Source: ABIH-RJ, Fecomércio-RJ (2014).

The total accommodation capacity in the city of Rio de Janeiro amounts to some 59,000 bed spaces (ABIH, 2014). It was assumed that all guest categories present the lowest waste generation rate of the Copacabana Palace (23 liters/guest-day), even though 5 stars guests probably generate more waste than other categories. Others assumptions regard the specific gravity (0.2 kg/liter) and the occupancy rate (at 2013 values). These assumptions resulted in a typical generation of 195 t/day.

Regarding the supermarkets, the response rate was also low. The Association of Supermarkets of the State of Rio de Janeiro (ASSERJ) reported that its members account for 290 stores across the Rio de Janeiro territory, but was unable to inform their share in the total number of stores. As a result, the only available alternative was to assume these stores represent the universe and that their spatial distribution is a function of the state population, which is estimated by IBGE as 16.46 million inhabitants in the 1st of July, 2014. On the same date, the capital city housed 6.32 million people, which represents 38.39% of the state population. This was it is estimated that the City of Rio de Janeiro has 118 supermarket stores.

Taking into account that the Carrefour chain alone generates 8 t/day throughout its 7 stores (1.14 t/store-day) and that major stores together – Carrefour, Guanabara, Mundial, Prezunic, Pão de Açúcar, Zona Sul, Walmart – have about 49 stores in the municipality, then they generate about 56 tons of waste per day. Assuming the remainder 69 stores to be small-sized and independent, with a generating rate of half the value of that of large stores, their generation is estimated at 100 t/day; nevertheless, validation calculation is necessary to confirm this figure.

CEASA estimates its own generation to be about 100t/day, comprising mostly organic matter. Since there are no scales at the entrance gate, their office is unable to establish a precise value, but their approximate figure is 3 to 4% of received materials. As a result, supermarkets add up to 200t/day.

The few Transporters that reported daily handled quantities do not separate them into client types, which prevented their use in this Diagnosis. Information on Disposal Facilities were not employed either.

6. CONCLUSIONS

Since this was the first round of research, the work was carried out with little information, as the number of returned questionnaires was insufficient to enable satisfactory precision for every sector, except for Communities and Disposal Facilities of Civil Construction Waste (CCW), as observed from the CVs presented in table 26, below.

It should be noted that, in this table, the values of Coefficients of Variation, Total Estimators and Standard Deviations of the Estimation were extracted from the results obtained for each investigated Sector. Since the only data source for Large Generators (LG) estimates concerns Shopping Malls, presenting a CV of 24.15%, this value was adopted for the whole Large Generators, sector notwithstanding its accuracy falling below the acceptable level, for the lack of more reliable data.

Table 26. Estimates of Waste Generation – per Sector and Total

Sector	CV (%)	Total Estimator (t/day)	Total Estimation SD (t/day)
Communities (irregularly disposed)	5.80	253.66	14.71
Civil Construction (CCW)	2.71	9,116.85	247.89
Household and Public	0.00	8,252.00	0.00
Effluent (sludge)	0.00	11.65	0.00
Large Generators	24.15	531.79	128.43
Industry	27.31	1,132.80	309.37
Recycling	0.00	43.83	0.00
Health Services (HSW)	54.03	124.7	67.38
Total RJ	2.17	19,467.28	422.39

Source: Own elaboration (2014).

Notes - SD =Standard Deviation= Square root of the variance of total estimation

CV = Coefficient of Variation = SD/Total estimation; null where Census was conducted.

Figure 8 below presents the percentage shares of Total Estimators per sector.

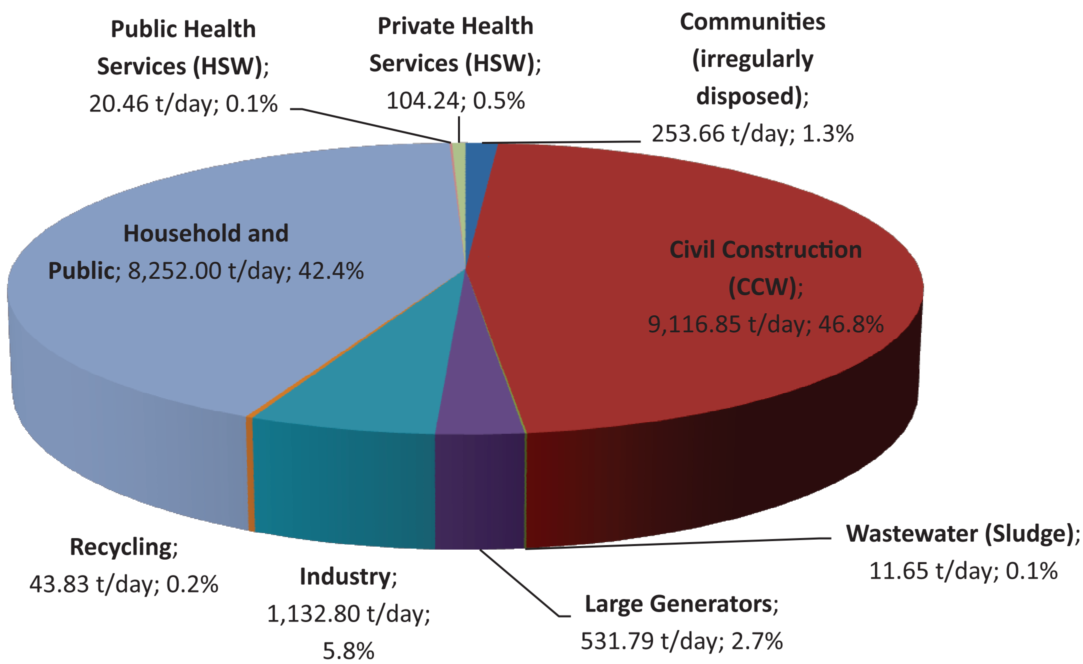

Figure 8 Preliminary Diagnosis of Solid Waste Management in the City of Rio de Janeiro – 2015 – Estimated results of daily waste generation in t/day and respective shares[20]

Despite the low response rates to questionnaires applied during the primary research, it was possible to estimate the total generation of waste through the sum of total estimators of Table 26.

After that, as described in the methodology, the standard deviation of the total estimation was calculated, and it was then divided by the estimator to obtain the Total CV, as shown in the last line of the Table. Since the Total CV of the Diagnosis reached 2.17%, which can be considered as excellent, it is possible to use a 90% confidence interval for all the sectors, as described in the "Estimation Method".

The threshold values of the 90% Confidence Interval correspond to the calculated Total Estimator ±1.65 times the Estimation SD, which are deemed as accurate when the confidence interval margin is less than 10% of the total estimator, as presented below in Table 27.

[20]It was not possible to establish in this Preliminary Diagnosis the CCW quantities reused directly by ongoing major construction works in the City, either on the very construction sites or on other facilities of the generators. Only CDURP, the company in charge of the revitalization of the port area, informed its average daily waste recycling of 987.30 tons, which represents 98% recycling in 2014. It is important highlighting that other major projects, such as the BRT (Bus Rapid Transit), recorded approximately 1,267,300 tons of reused waste from the beginning of works (article published on O GLOBO – Rio section, Monday 15 Dec., 2014, p.6).

Table 27. Estimates of Waste Generation per Sector

Sector	Confidence interval of 90% (t/day)	
Communities (irregularly disposed)	228.29	279.00
Industry	622.34	1,643.26
Civil Construction (CCW)	8,707.63	9,527.85
Recycling	43.83	43.83
Health Service (HSW)	13.53	235.87
Domestic and Public	8,252.00	8,252.00
Effluent (sludge)	11.65	11.65
Large Generators	319.88	743.70
Total RJ	**18,200.44**	**20,734.12**

Source: Own elaboration (2014).

Notes - SD =Standard Deviation= Square root of the variance of total estimation

CV = Coefficient of Variation = SD/Total estimation.

It is possible to infer from Table 27 above that the estimation of the municipal generation of waste is contained within the interval from 18,201 to 20,735 tons per day. The sectors with largest representation are Civil Construction (CCW), with a 46.8% share of total waste, followed by Household and Public (waste collected from households, small generators and public areas by COMLURB), contributing 42.4% to total waste generation. In a second group are Industry and Large Generators (LG), with 5.8% and 2.7%, respectively; these low values are possibly a result of the low response rates to questionnaires.

Because over half the waste comes from Construction, it should be noted that most public works carried out in recent years arise out of commitments to international events concentrated within one decade's time. This can be considered as an atypical situation and requires further examination into the natural evolution of the CCW.

During the primary research work on Disposal Facilities, it was observed an installed capacity for Civil Construction waste (CCW) of approximately 4,700 t/day. However, it was not possible to obtain further data neither on the actual use of this equipment nor on the reuse of CCW.

It is worth mentioning that CDURP reported sending 1,000 t/day of materials to recycling. Nevertheless, since it was the only Generator to provide this type of information, it was not possible to assess the overall recycling potential of this sector.

Considering that the totality of the universe of each sector could not be quantified, efforts in establishing standards for better control and collection of information from the spheres involved are strongly advised.

With regard to the interval margin, calculated by multiplying the factor of the confidence interval adopted (1.65) by the CV, communities present a value of 9.57% of the total estimator, which can be considered a good result. The margin for RCC is 4.49%, which configures a great result. On the other hand, the margins obtained for Large Generators (40%) and Industry (45%) are poor. The result for RSS, which exceeds 89%, may be regarded as terrible. **Nevertheless, the margin of the total estimation, namely 6.51%, can be considered as excellent.**

For the purpose of estimating waste generation for other years, an analysis was conducted on the correlation between the actual waste quantities generated by each sector and the evolution of the municipal GDP, which presented coherent results of varying degrees in all the sectors for which data was obtained. The equations are available in item 3 of this Diagnosis.

Regarding emissions of gases contributing to global warming, out of the surveyed sectors Household and Public Waste is the most important one, because of its significant organic contribution (50%), which justified further laboratory testing in order to detect macromolecules (such as proteins, carbohydrates, and lipids) that can potentially generate methane. The resulting data was applied to the anaerobic digestion equation, resulting in more than 500m^3 of methane (CH_4) per ton of organic matter. In order to confirm the actual generation of biogas and its methane content, it is important to carry out experimental studies and obtain actual data. This set of characterization and anaerobic digestion tests will be extended to the remaining sectors for the purpose of assessing their effective contributions.

It must be emphasized that emissions related to the logistics of waste management are considered under the "Transport" item of GHG Inventory for the City (ROVERE et al., 2013).

Therefore, it is recommended that any research to be carried out with the same goals make use of the data found in this work for sample planning purposes. In addition, they must obtain adequate samples in both the quantitative aspect – the number of responses has to be coherent with the calculated sample sizes – and the qualitative one – using samples that can be considered as random and present appropriate properties.

In view of the need to increase the number of responses to questionnaires in the next editions of the Diagnosis of Solid Waste Management in the City of Rio de Janeiro and consequently improve its quality in all investigated sectors, this first work should be widely disseminated highlighting its central importance as a policy planning tool. Its use is of the utmost importance to identifying the most representative agents, the types of waste generated, and the required actions in order to reduce waste and/or to promote its exploitation, and its elaboration depends on the direct participation of key entities from the sector to access relevant data.

Because of the novelty of the research work herein conducted, it can be observed the need of creating legislative instruments (agreements, decrees, resolutions, and the like) for mandatory reporting of information on generation, transport, and disposal of waste and effluents from all sources.

This study represents the first step towards a complete assessment of waste management in the city of Rio de Janeiro and the definition of guidelines for action, in view of Greenhouse Gas (GHG) emission cuts and mitigation goals established by the city government, and in the quest of increased social, environmental, and economic benefits for a more resilient city.

7. REQUIREMENTS FOR FUTURE UPDATES TO THE DIAGNOSIS

During the work for the elaboration of this Preliminary Diagnosis of Solid Waste Management in the City of Rio de Janeiro, some opportunities were identified for further additions to the study, as presented below:

- Establishing legal mechanisms for mandatory reporting of waste data and quantities by generators, transporters and disposal facilities.
- Establishing information systems to gather data on waste from construction, renovation and demolition sites authorized/executed by the various Municipal Secretariats, especially those of Urban Planning, City Works, Housing, Public Conservation and Services, and Environment.
- Complementing the information on industrial waste generation based on the FIRJAN records with data on municipal and state level environmental licenses.
- Evaluating the current projections for waste generation based on Gross Domestic Product – GDP, and, if appropriate, establishing a different methodology for updated estimates.
- Complementing the estimate of waste by Large Generators (LG) with data on street shop activities (including shops, restaurants, pharmacies, and the like).
- Complementing estimates for the Recycling sector with data on all types of recyclables, beyond those adopted in this edition of the research (Table 15).

BIBLIOGRAPHY

ASSOCIAÇÃO BRASILEIRA DA INDÚSTRIA QUÍMICA – ABIQUIM. Anuário da Indústria Química Brasileira. 2006.

ASSOCIAÇÃO BRASILEIRA DE EMPRESAS DE LIMPEZA PÚBLICA E RESÍDUOS ESPECIAIS. – ABRELPE. Panorama dos Resíduos Sólidos no Brasil, 2011-2013.

ASSOCIAÇÃO BRASILEIRA DE EMPRESAS DE LIMPEZA PÚBLICA E RESÍDUOS ESPECIAIS – ABRELPE. Panorama dos Resíduos Sólidos no Brasil, 2013.

ASSOCIAÇÃO BRASILEIRA DE SHOPPING CENTERS – ABRASCE. http://www.portaldoshopping.com.br/numeros-do-setor/shoppings-nas-capitais-brasileiras

ASSOCIAÇÃO DOS ADMINISTRADORES DE IMÓVEIS – ABADI. Cooperativas de Catadores Cadastradas do Estado do Rio de Janeiro. 2013. Disponível em: <http://www.abadi.com.br/downloads/coletaseletiva_cooperativas.pdf>. Acesso em: 10 set. 2013.

ASSOCIAÇÃO BRASILEIRA DE EMPRESAS DE LIMPEZA PÚBLICA E RESÍDUOS ESPECIAIS – ABRELPE. Panorama dos Resíduos Sólidos no Brasil. 2013.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. NBR 6023: informação e documentação: referências: elaboração. Rio de Janeiro, 2002a, 24 p.

______.NBR 8.419. Apresentação de projetos de aterros sanitários de resíduos urbanos – Procedimento. 1987.

______. NBR 10004: resíduos sólidos: classificação. Rio de Janeiro, 2004a, 71 p.

______. NBR 10006: procedimento para obtenção de extrato solubilizado de resíduos sólidos. Rio de Janeiro, 2004b, 3 p.

______. NBR 10007: amostragem de resíduos sólidos. Rio de Janeiro, 2004c, 21 p.

______. NBR 10520: informação e documentação: citações em documentos: apresentação. Rio de Janeiro, 2002b, 7 p.

______. NBR 12808: resíduos de serviços de saúde: classificação. Rio de Janeiro, 1993a.

______. NBR 12809: manuseio de resíduos de serviços de saúde: procedimento. Rio de Janeiro, 1993b.

BAIRD; C. Química Ambiental. 2ªed. Porto Alegre: Bookman, 2002.

BANCO NACIONAL DE DESENVOLVIMENTO ECONÔMICO E SOCIAL – BNDES. Análise das Diversas Tecnologias de Tratamento e Disposição final de Resíduos Sólidos Urbanos no Brasil, Europa, EUA e Japão. Fundação de Apoio ao Desenvolvimento da Universidade Federal de Pernambuco, Grupo de Resíduos Sólidos, UFPE, 186 p., 2013.

BIDONE, F. R. A.; POVINELLI, J. Conceitos básicos de resíduos sólidos. São Carlos: EESC/ Universidade de São Paulo. 1999, 120p.

BOLFARINE, H. E BUSSAB, W., “Elementos de Amostragem”, Blücher, 2011.

BRASIL. Lei Federal nº 12.305, de 02 de agosto de 2010. Estabelece a Política Nacional de Resíduos Sólidos.

CASTILHO JUNIOR, A. B. Resíduos Sólidos Urbanos: Aterro Sustentável para Municípios de Pequeno Porte. PROSAB 3, ABES, 2003.

CASTILHO JUNIOR, A. B. Gerenciamento de Resíduos Sólidos Urbanos com Ênfase na Proteção de Corpos D'água: Prevenção, Geração e Tratamento de Lixiviados de Aterros Sanitários. PROSAB 4, ABES, 2006.

CLASSIFICAÇÃO NACIONAL DE ATIVIDADES ECONÔMICAS. CNAE. Comissão Nacional de Classificação(CONCLA). Disponível em: <http://www.cnae.ibge.gov.br/>. Acesso em: 5 nov. 2013.

COCHRAN, W.Sampling Techniques, Ed. Wiley.1977.

COMPANHIA MUNICIPAL DE LIMPEZA URBANA – COMLURB. Caracterizações Gravimétrica e Bacteriológica de Resíduos Sólidos Domiciliares da Cidade do Rio de Janeiro –Relatório Anual 2012. Diretoria Técnica e Industrial. Gerência de Pesquisas Aplicadas, Rio de Janeiro, RJ, 105 p. 2012.

______.Comunicação pessoal a partir de Análise Gravimétrica dos resíduos sólidos urbanos recolhidos pela COMLURB para o Município do Rio de Janeiro – 2012, Paulo Jardim, sobre Coleta Domiciliar, Lixo Público e Entulho. 2014a.

______. Empresas credenciadas pela Comlurb para remoção de resíduos sólidos extraordinários, resíduos biológicos e resíduos sólidos inertes. 2014b. Disponível em: <http://comlurbnet.rio.rj.gov.br/extranet/credenciadas/serv_credenc.asp>. Acesso em: 12 fev. 2014;

______. Portaria Comlurb nº 18, de 19 de fevereiro de 2014. Estabelece valores a serem praticados pela Companhia Municipal de Limpeza Urbana, na prestação dos Serviços Especiais. 2014c.

______.Coleta Seletiva – 2014: Caracterização em 30 Bairros do Rio de Janeiro. Diretoria Técnica e de Logística, Gerencia de Pesquisas Aplicadas. Fevereiro, 2014d. .

CONFEDERAÇÃO NACIONAL DA INDÚSTRIA – CNI. Encontros CNI Sustentabilidade – Equilíbrio que movimenta um mundo melhor. Água: Oportunidades e desafios para o desenvolvimento do Brasil. Rio de Janeiro, 2013.

______. Encontros CNI Sustentabilidade – Equilíbrio que movimenta um mundo melhor. 3ª Ed. Resíduos Sólidos: Inovações e Tendências para a Sustentabilidade. Rio de Janeiro, 2014a.

______. Proposta de Implementação dos Instrumentos Econômicos Previstos na Lei nº 12.305/2010 por meio de Estímulos à Cadeia de Reciclagem e Apoio aos Setores Produtivos Obrigados à Logística Reversa. Brasília, 141 p. 2014b.

______. Visão da Indústria Brasileira sobre a Gestão de Resíduos Sólidos. Brasília, 220 p. 2014c.

______Avanços da Indústria Brasileira Rumo ao Desenvolvimento Sustentável: Síntese dos Fascículos Setoriais: Brasília: CNI, 51p. 2012.

DEPARTMENT OF ENVIRONMENT, FOOD AND RURAL AFFAIRS – DEFRA.Waste Composition Analysis Guidance for Local Authorities. DEFRA Publications: London, UK, 2004.

DORMUSOGLU, E.; CORAPCIOGLU, M. Y.; TUNCAY, K. Landfill settlement with decomposition and gas generation, Journal of Environmental Engineering, ASCE, vol.131, nº9, pp. 1311-1321. 2005.

ECOMARAPENDI. Projeto Recicloteca: Quem recebe recicláveis. 2013. Disponível em: <http://www.recicloteca.org.br/quemrecebe.asp>. Acesso em: 13 out. 2013.

ETC/RWM – EUROPEAN TOPIC CENTRE ON RESOURCES AND WASTE MANAGEMENT. Municipal Waste Management and Greenhouse Gases. 2008.

_____. Projections of Municipal Waste Management and Greenhouse Gases.2011.

EHRIG, H.J. Prediction of gas production from laboratory scale tests, In: Proceedings Sardinia 1991. The Third International Landfill Symposium, Sardinia, Itália, Vol.1, pp.87-114.1991.

FEDERAÇÃO DAS INDÚSTRIAS DO RIO DE JANEIRO – FIRJAN. Gestão para Reaproveitamento de Materiais nas Indústrias do Rio. Súmula Ambiental, Edição Ambiental, Gerência de Meio Ambiente Rio de Janeiro, RJ. 2004.

______. Informações estratégicas para o desenvolvimento do Estado do Rio de Janeiro. Retratos Regionais,4 ed. Rio de Janeiro, RJ, 2011.

______. Cadastro industrial do Estado do Rio de Janeiro 2011-2012. Rio de Janeiro, RJ. 2012.

______. Cadastro industrial do Estado do Rio de Janeiro 2012-2013. Rio de Janeiro, RJ. 2013.

______. Indicadores Industriais. Resultado da Indústria de Transformação. Rio de Janeiro, RJ. 2013.

______. Comunicação pessoal com Ivan Silva em 17/10/2013.

FEIRA FEITA. Disponível em:<www.feirafeita.com.br>. Acesso em: 14 jan. 2014.

FÉRES, J. G.; THOMAZ, A.; REYNAUD, A.; SEROA DA MOTTA, R. Demanda por Água e Custo de Controle da Poluição Hídrica em Indústrias da Bacia do Rio Paraíba do Sul. IN: Campos, José Nilson B. (Org.). Recursos Hídricos: Prêmio Jovem Pesquisador 2005. Fortaleza: ABRH, 2005. P. 277-304.

FIBRASA. Disponível em: <http://www.fibrasa.com.br/>. Acesso em: 13 jan. 2014.

Fórum da Reciclagem – Disponível em <http://forumdareciclagem.org.br>. Acesso em 15 jan 2014.

Fundação Centro Estadual de Estatísticas - CEPERJ Pesquisas e Formação de Servidores Públicos do Rio de Janeiro. Anuário Estatístico do Estado do Rio de Janeiro. Diagnóstico sobre a Economia Fluminense Baseado nos Projetos Contas Regionais do Brasil e PIB Municipal. 2010

GOMES, L. P. (Coordenadora). Resíduos Sólidos: Estudos de Caracterização e Tratabilidade de Lixiviados de Aterros Sanitários para as Condições Brasileiras. PROSAB 5, ABES, 2009.

GUNASEELAN,V.N.Regression models of ultimate methane yelds of fruits and vegetable solid wastes, sorghumandnapiergrassonchemicalcomposition. 2007. Bioresource Technology, v. 98, p. 1270-1277.

HARADA, T. M.; PHILIPPI, S. T. Padronização de medidas usuais de consumo de frutas das regiões Centro-Oeste e Nordeste Brasileiras. FSP/USP. 2006.

HORTIFRUTI. Disponível em:<www.hortifruti.com.br>. Acesso em: 15 jan. 2014.

INSTITUTO BRASILEIRO DE ADMINISTRAÇÃO MUNICIPAL. Manual de Gerenciamento Integrado de Resíduos Sólidos. Rio de Janeiro: IBAM, 2001.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA – IBGE, Censo Demográfico 2010 – Aglomerados Subnormais – primeiros resultados, Rio de Janeiro, RJ. 2011.

______. Diretoria de Pesquisas, Coordenação de Indústria. Índice base fixa da geração física da indústria de transformação por setor de atividade do município do Rio de Janeiro de 2002 até 2012. Classificação Nacional de Atividades Econômicas (CNAE). 2012.

______.Introdução à Classificação Nacional de Atividades Econômicas. CNAE 2.0 2010. Disponível em: http:>//ibge.gov.br/concla/pub/revisao2007/PROPCNAE20/CNAE20_

Acesso em: agosto de 2013.

______.Pesquisa de Serviços de Tecnologia da Informação 2009 Nota Técnica. Disponível em:<http://www.ibge.gov.br/english/estatistica/economia/psti/2009/notas_tecnicas.pdf>. Acesso em: 2 out. 2013.

______. Valor do rendimento nominal médio mensal, valor do rendimento nominal mediano mensal das pessoas com rendimento, responsáveis pelos domicílios particulares permanentes, segundo as Áreas de Planejamento, Regiões Administrativas e Bairros – 2000/2010. In: Armazém de Dados – Instituto Pereira Passos, 2010. Disponível em: <http://portalgeo.rio.rj.gov.br/amdados800.asp?gtema=15>. Acesso em: 05 dez. 2013.

INSTITUTO DE PESQUISA ECONÔMICA APLICADA – IPEA. Diagnóstico dos ResíduosSólidos Industriais. Relatório de Pesquisa. Brasília, DF. 2012.

INSTITUTO DE PESQUISAS TECNOLÓGICAS – IPT/CEMPRE. Lixo Municipal: Manual de Gerenciamento Integrado. D'Almeida, Maria Luiza Otero; Vilhena, André. 2 ed., São Paulo, SP. 2010.

INSTITUTO ESTADUAL DO AMBIENTE – INEA. Autos Emitidos em 2013. Disponível em:<http://www.inea.rj.gov.br/licenciamento/Autos_Emitidos.asp>. Acesso em: 24 set. 2013.

______. Banco de Dados. Disponível em: <http://sistemas.inea.rj.gov.br/meioambiente/portal/login.aspx>. Acesso em: 24 set. 2014.

______.Plano Estadual de Resíduos Sólidos (PERS) Volume 2: Diagnóstico de Resíduos Sólidos – Tomo II, Agosto, 2013.

INSTITUTO PEREIRA PASSOS – IPP. Painel da Economia Carioca. 2013. Diretoria de Desenvolvimento Econômico Estratégico, Prefeitura Municipal do Rio de Janeiro.Disponível em: <http://ipprio.rio.rj.gov.br/>. Acesso em: 26 set. 2013.

MACIEL, F.J.Estudo da geração, percolação e emissão de gases no Aterro de Resíduos Sólidos da Muribeca/PE. Dissertação de Mestrado – Centro de Tecnologia e Geociências, Universidade Federal de Pernambuco, Recife-PE, 2003, 173p.

McBEAN, E.A., ROVERS, F.A., FARQUHAR, G.J., Solid Waste Landfill Engineering and Design. PRENTICE HALL PTR, 1995.

MINISTÉRIO DO MEIO AMBIENTE.Resolução Conama nº 307, de 5 de julho de 2002. Estabelece diretrizes, critérios e procedimentos para a gestão dos resíduos da construção civil.

______. Resolução Conama nº 313, de 29 de outubro de 2002. Dispõe sobre o Inventário Nacional de Resíduos Sólidos Industriais.

______. Resolução Conama nº 348, de 16 de agosto de 2004. Altera a Resolução Conama nº 307, de 5 de julho de 2002,incluindo o amianto na classe de resíduos perigosos.

______. Resolução Conama nº 431, de 24 de maio de 2011. Altera o art. 3º da Resolução nº 307, de 5 de julhode 2002, do Conselho Nacional do Meio Ambiente, estabelecendo nova classificação para ogesso.

______. Plano Nacional de Resíduos Sólidos – Versão Preliminar. Instituto de Pesquisa Econômica Aplicada, Brasília, DF, set. 2011.

______. Resolução Conama nº 448, de 18 de janeiro de 2012. Altera os artigos 2º, 4º, 5º, 6º, 8º, 9º, 10 e 11 da Resolução nº307, de 5 de julho de 2002, do Conselho Nacional do MeioAmbiente.

MINISTÉRIO DAS CIDADES (2012). Sistema Nacional de Informações sobre Saneamento. Diagnóstico do Manejo de Resíduos Sólidos 2010.Tabelas de informações e indicadores. Brasília.www.snis.gov.br Acesso em 27-09-2013.

______. (2013). Sistema Nacional de Informações sobre Saneamento. Diagnóstico dos Serviços de Água e Esgoto. 2013. Tabelas de informações. Brasília.www.snis.gov.br Acesso em 16-11-2014.

MOURA, P.; HONAISER, A.; BOLOGNINI, M. Avaliação do Índice de resto ingestão e sobras em unidade de alimentação e nutrição do colégio agrícola de Guarapuava – Paraná. Universidade Estadual do Centro-Oeste (Unicentro).2010.

NEI –Revista especializada para profissionais da indústria. http://www.nei.com.br/topfive/. Norma NBR 10 004, ABNT – Associação Brasileira de Normas Técnicas.

PLASTIKERO. Disponível em:<http://www.plastikero.com.br/>. Acesso em: 13 jan. 2014.

Plano Nacional de Resíduos Sólidos. Ministério do Meio Ambiente. Instituto de Pesquisa Econômica Aplicada.

POLÍTICA NACIONAL DE RESÍDUOS SÓLIDOS – PNRS. LEI Nº 12.305, DE 2 DE AGOSTO DE 2010.

PREFEITURA DA CIDADE DO RIO DE JANEIRO (2012). Plano Municipal de Gestão Integrada de Gestão de Resíduos Sólidos – PMGIRS da Cidade do Rio de Janeiro – agosto de 2012 a agosto de 2016

RESOLUÇÃO CONAMA Nº 313, DE 29 DE OUTUBRO DE 2002. Dispõe sobre o Inventário Nacional de Resíduos Sólidos Industriais.

REVISTA ESPECIALIZADA PARA PROFISSIONAIS DA INDÚSTRIA – NEI. Disponível em: <http://www.nei.com.br/topfive/>. Acesso em: 19 set. 2013.

RECIO, MARIA ANGELES LOBO; CARRERA, LUIZ CARLOS MARQUES.Química Ambiental/Colin Baird. Trad., 2ed., Porto Alegre: Bookman. 2002.

RIO DE JANEIRO (Município). Lei Municipal nº 3.273, de 6 de setembro de 2001, que dispõe sobre a gestão do sistema de limpeza urbana no Rio de Janeiro.

ROMER, D. Advanced Macroeconomics. New York: McGraw-Hill, 1996. p. 5-25. ISBN 0-07-053667-8.

ROVERE, Emilio Lèbre La; CARLONI, Flávia Beatriz; LOUREIRO, Saulo Machado; TURANO, Patrícia; SOLARI, Renzo; NADAUD, Gabriela; MALAGUTI, Gustavo; ARAGÃO, Raymundo; BREDARIOL, Tomás. III Inventário das Emissões de Gases de Efeito Estufa da Cidade do Rio de Janeiro e Atualização do Plano de Ação Municipal para Redução das Emissões. Rio de Janeiro: Centro Clima/COPPE/UFRJ, Secretaria Municipal de Meio Ambiente – SMAC. Dez. 2013. 230 p.

SECRETARIA MUNICIPAL DE MEIO AMBIENTE – SMAC. Comunicação pessoal com Paulo Carneiro em: 16 out. 2013, 21 out. 2013, 21 jan. 2014.

______.Prefeitura da Cidade do Rio de Janeiro. Relação de empresas Licenciadas para a destinação ambiental de resíduos da construção civil. 2013. Disponível em: <http://www.rio.rj.gov.br/dlstatic/10112/148105/4107003/Tabela_empresas_beneficiamento_RCC_09.08.2013.pdf>. Acesso em: 09 ago. 2013.

______.Comunicação pessoal com Paulo Carneiro em 16/10/2013 e 21/10/2013.

SERVIÇO BRASILEIRO DE APOIO ÀS MICRO E PEQUENAS EMPRESAS – SEBRAE. Disponível em: <www.sebrae.com.br>. Acesso em: 14 jan. 2014.

SM Supermercado ModernoTop Five Fornecedores, Guia Prático de Sortimento . . Disponível em: <www.sm.com.br>. Acesso em: agosto de 2013, Ano 20. 2013.

SOARES, E. L. S. F. Estudo da caracterização gravimétrica e poder calorífico dos resíduos sólidos urbanos. Dissertação (de mestrado). Programa de Engenharia Civil. COPPE/UFRJ. 2011.

STUART, A. Basic Ideas of Scientific Sampling. Ed. Griffin. 1968.

SUPERMERCADO MODERNO – SM. Top Five Fornecedores Ano 20. Guia Prático de Sortimento. Disponível em: <www.sm.com.br>. Acesso em: 30 ago. 2013.

TCHOBANOGLOUS, G.; THEISEN, H.; VIGIL, S. Integrated Solid Waste Mangement – Engineering Principles and Management Issues. Ed. Irwin/Mc Graw-Hill, USA. 1993.

UNIÃO EUROPEIA: Directiva 1999/31/CE do Conselho.

WORLD HEALTH ORGANIZATION – WHO. InternationalReference Center for WasteDisposal. Methodsofanalysis os sewagesludgesolidwastesandcompost. Switzerland, 1997.

WORLD BANK. What a Waste. A Global Review of Solid Waste Management. 2012