Construction and Demolition Waste (C&D): An Overview of the Reception Areas in the City of Belo Horizonte / Brazil

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***Abstract*– Municipal Solid Waste (MSW) management has become more complex and costly with rapid socioeconomic development and increased waste volume. In this context, stand out Construction and Demolition Waste (C&D), considering that, they represent a large part of the solid waste generated in the urban environment. One of the main impacts faced by municipalities in relation to construction waste is associated with the irregular disposition of the enormous quantities produced and the expenses of the public administration with corrective management models. This study aims to present an overview of the current reception locations of C&D in the city of Brazil (Belo Horizonte), evaluating its efficiency in municipal management. In order to reach the proposed objective, references were used based on reports from the municipality and through bibliographical research, carried out in articles, municipal management plan and current legislation. Based on the results obtained, it can be seen that the municipality has a good structure for the management of C&D, in accordance with the requirements of CONAMA Resolution No. 307/2002. However, although SLU provides appropriate waste reception facilities, it is still possible to see several locations of irregular C&D disposal. It is concluded that there is a great deficiency regarding the measures related to the non-generation, the minimization, the disposition and the reutilization of the C&D generated in the city. Finally, it is suggested some measures that could be adopted to improve, especially related to the current areas of reception, the management of C&D in the city of Belo Horizonte.**

***Keywords*– Construction and Demolition Waste, Municipal Solid Waste, Waste Disposal and Waste Management**

I. INTRODUCTION

The intense urbanization process with consequent densification of urban centers began in Brazil in the 1950s, provoking serious social, environmental and health problems in many cities, especially those in which there was rapid and disorderly growth. According to [1], these last problems are caused, in most cases, by the inadequate management of Municipal Solid Waste (MSW), among them wastes from construction, called Construction and Demolition Waste (C&D).

The construction industry plays a significant role in the economic and social development of the country, generating employment, income and commercialization of inputs, equipment and services in its productive process; however, the major challenge today is to reconcile economic development and environmental preservation [2].

Researches carried out in Brazil on the particularities of sustainable cities have pointed to civil construction as a sector to be improved, considering that it causes great impact to the environment due to the consumption of natural resources or extraction of materials from deposits; of the consumption of electric energy in the stages of extraction, transformation, manufacture, transportation and application of the materials; the generation of waste due to losses, waste and demolition, as well as deforestation and changes in land use [3].

The report prepared by the Institute for Applied Economic Research (IPEA) [4] estimated a national production of about 31 million tons/year of Construction and Demolition Waste. Since [5] quantifies the C&D generation between 0.40 and 0.76 tons/inhabitant/year, based on the average of some Brazilian cities. According to [6], the methodology used in the RCD generation estimates can cause great variability in the values when analyzing different sources for the same country.

Table I demonstrates the estimates of C&D generation in different countries of the world, according to [6].

TABLE I
ESTIMATES OF C&D GENERATION IN COUNTRIES OF THE WORLD

County	Annual amount	
	Mt	kg/inhabitants
Germany	79 - 300	963 - 3658
Brazil	NI	230 - 660
United States	136 - 171	463 - 584
Netherlands	13 - 20	820 - 1300
Japan	99	785
Portugal	3	325
Sweden	1 - 6	136 - 680

Adapted from [6]. NI - Not informed by the author

[7] argues that waste from construction, refurbishment or demolition (consisting of concrete, brick, soil, rock, and other inert materials) when deposited in inappropriate places could lead to serious environmental problems. There are several difficulties regarding the treatment and final destination of C&D, one of the main ones being the lack of accurate information about the number of areas that receive this type of material and its characteristics, data indispensable for urban planning, waste and also of investors in the sector.

Another relevant point is the implementation of the efficient management of Construction and Demolition Waste, in order to avoid reworking costs and reduce damages related to deposition in inappropriate locations. For sustainable management of C&D, capturing, collecting and recycling these can be an effective tool [8].

This situation generates a constant need for public policies and technical-scientific solutions for collection and disposal, as well as the feasibility of recycling and reuse of solid urban waste, particularly those generated by civil construction. In this context, this paper intends to present an overview of the receiving areas of Construction and Demolition Waste present in Belo Horizonte/Brazil. There were 34 units for receiving small volumes (named by the acronym URPV in portuguese), 2 stations for rubble recycling (named by ERE) and several irregular deposition sites in the city.

II. METHODOLOGY

According to [9], the lack of an established standard that allows the adoption of a single procedure, with regard to the research methodology, makes the choice of methodological framework vary according to the research objectives.

Therefore, the definitions about this theme have as starting point the selection of the methodological structure most appropriate to the nature of the research [9]. In this sense, for the development of the present work, the methodological structure proposed by [10] was defined:

i. *Objective of the research*: Exploratory.
ii. *Nature of research:* Conceptual.
iii. *Logic of research:* Inductive and Deductive.
iv. *Research process:* Qualitative and Quantitative.
v. *Search results:* Basic.
vi. *Technical procedures:* Bibliographic research.
vii. *Instruments:* Books, articles, reports, management plans and national legislation.

The methodology adopted in this research was based on the division of the study of the panorama of the reception areas of C&D in Belo Horizonte in three stages. The first referring to the description of the basic data of the city, the second consisted of the presentation of concepts of generation and destination of the C&D and, finally, an analysis of the public organization used in the management of C&D of the municipality. Fig. 1 systematizes the study steps.

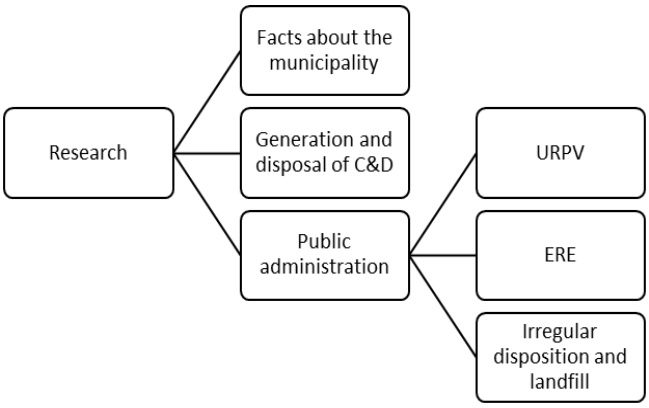

Fig. 1. Research methodology developed. Prepared by the author

The information of the first stage was obtained through data from the Brazilian Institute of Geography and Statistics (IBGE) and the Belo Horizonte City Hall (PBH). For the second stage, concepts presented in the CONAMA Resolution [11] were used. Finally, data obtained from the Municipal Integrated Solid Waste Management Plan (MISWMP) [12] and the Superintendência de Limpeza Urbana (SLU) were used in the third stage.

Throughout the article, references were also made to academic papers in Brazil and other countries to assist in the analysis of the panorama of the reception areas of C&D in the city of Belo Horizonte.

III. RESULTS AND DISCUSSIONS

A) Basic facts about Belo Horizonte

The municipality of Belo Horizonte, capital of the State of Minas Gerais, is located in the southeastern region of Brazil. The municipal seat is located at 852 meters of altitude, and can reach 1,395 meters, at the top of the Curral mountain range. It has a territorial area of 331.4 km² and an estimated population of 2.5 million inhabitants, representing a population density of 7,544 inhab / km², according to [13]. The city is divided into nine regional (like local prefectures) that are in charge of attending the public service of the neighborhoods that compose them [14]. Fig. 2 shows the population and area distribution by region (Barreiro, Centro-Sul, Leste, Nordeste, Noroeste, Norte, Oeste, Pampulha e Venda Nova).

According to [14], municipal waste management comprises public sweeping and weeding services, collection of solid waste (domestic and special, including C&D), treatment and disposal of waste. Data from the [15] indicate that 404,748.31 tons of C&D were collected in URPV, in irregular locations and by private and public emitters, representing 32.3% of the total solid waste collected in Belo Horizonte. Of this total, only 49,839.24 t (12.3% of C&D collected in the city) were sent for recycling. Table II presents the city's solid waste destination by type, according to [15].

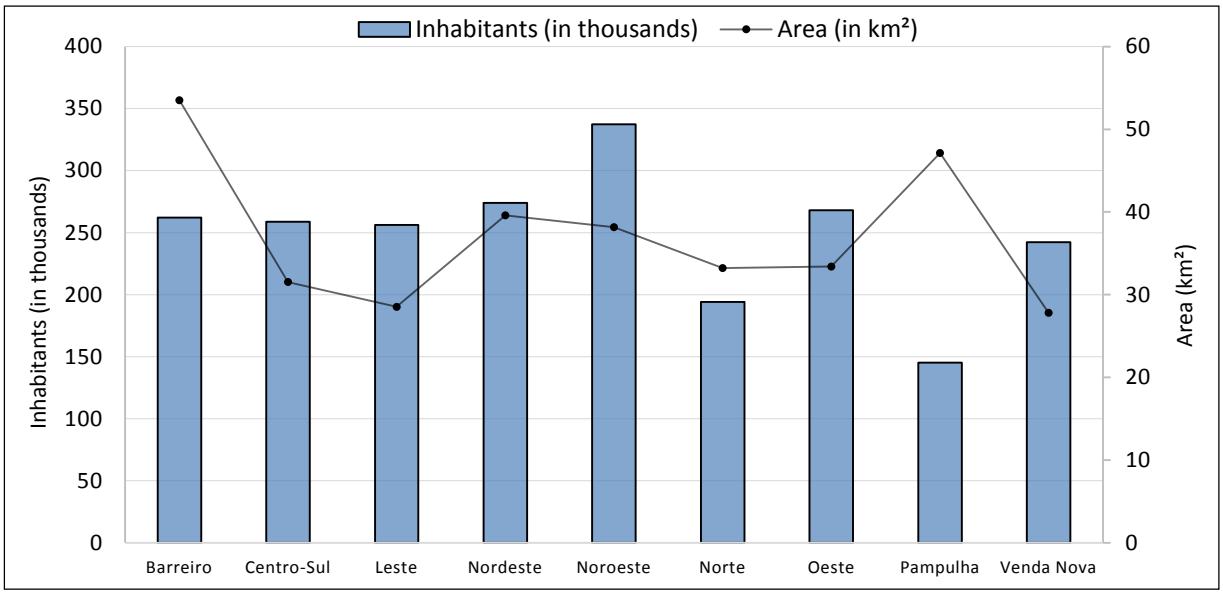

Fig. 2. Population and area distribution by region. Adapted from [13]

TABLE II
DESTINATION OF SOLID WASTE IN BELO HORIZONTE BY TYPOLOGY

Waste type	Origin	Quantity (t)	Treatment/ Destination	Local
Health's waste	Health facilities	9,168	Grounding	BR-040
MSW	Home and urban cleaning	828,157	Landing	Macaúbas
	Selective organic collection	2,525	Composting	BR-040
	Selective collection	6,636	Screening and Recycling	Association cooperative
	Pruning of public afforestation	261	Composting	BR-040
	URPV and irregular places	354,909	Screening and Landing	Maquiné
C&D	Private and public	29,995	Screening and Recycling	ERE - Pampulha
		19,843	Screening and Recycling	ERE - BR-040
Total waste			1,251,497.63 t	

B) Generation of construction and demolition waste

The C&D is composed of all the waste materials used to carry out civil construction activities. They come from the stages of demolition, infrastructure, renovation, restoration, repairs and new construction, i.e., all fragments or remains of stone materials, sands, ceramic materials, mortar, concrete, steel and wood [16].

The impacts caused to the environment due to the inadequate disposal of C&D are one of the major problems in the management of municipalities, as they may compromise the local landscape, pedestrian and vehicles traffic and urban drainage [17]. In this way, CONAMA Resolution No. 307/2002 was sanctioned with the purpose of assisting in the demands related to the management of the C&D and establishes guidelines, criteria and procedures for their management, being the main regulating regulation of all stages of the waste stream.

The aforementioned Resolution classifies waste generated in construction activities, prohibits landfilling of municipal solid waste and non-regularized sites for this type of activity and establishes the appropriate destinations for each class of waste, as indicated in Table III.

TABLE III
CLASSIFICATION AND DESTINATION OF C&D

Class	Description	Destination
A	Reusable or recyclable waste as aggregates, including earths from earthworks, ceramic components, mortar and concrete.	Reused or recycled in the form of aggregates, or sent to landfill areas of construction waste, being arranged so as to allow their use or future recycling.
B	Recyclable waste for other destinations, such as plastics, paper, cardboard, metals, glass, wood, empty packaging of real estate paints and plaster.	Reused, recycled or transported to temporary storage areas and disposed of in a way that allows them to be used or recycled in the future.
C	Wastes for which no economically viable technologies or applications have been developed to allow their recycling or recovery.	Stored, transported and destined in accordance with the specific technical standards.
D	Hazardous C&D	

In this way, it is added that the C&D have different natures, and may vary according to the place of generation, the modernization developed in the construction, the diversities

related to the material applied in the work, the quality of the project and the workforce employed [18]. Therefore, its treatment must be carried out within the construction sites, with organization and segregation of the materials for later reuse or future recycling [19].

In general, the CONAMA Resolution No. 307/2002 discriminates the areas of destination of the C&D using the following technical terms:

- *Waste disposal areas*: These are areas for the processing or disposal of waste.
- *Class A waste landfill*: Technically suitable area, where techniques for the disposal of C&D class A in the soil will be used, aiming at the reservation of segregated materials, allowing its future use or use of the area.
- *C&D transshipment and sorting area*: Area to receive C&D and bulk residues, for sorting, temporary storage of segregated materials, eventual transformation and subsequent removal to appropriate destination.
- *Processing*: It is the act of subjecting a waste to operations and/or processes that aim to provide them with conditions that allow them to be used as raw material or product.
- *Recycling*: It is the process of reuse of a waste, after having undergone the transformation.

C) Public organization in C&D management

On August 2, 2010, Brazil approved Federal Law No. 12.305, which implemented the National Policy of Solid Waste (NPSW), establishing guidelines that should be adopted for the management of solid waste in the country. The legislation emphasizes the importance of hierarchical management actions: not generating waste, reducing its production, reusing, recycling, treating and performing the final disposal environmentally appropriate waste should be the hierarchical sequence conducted in all projects related to solid waste management [20].

In the municipal range, Law No. 10.534/2012 provides for urban cleaning, its services and MSW management in Belo Horizonte, which supported the development of works resulting in the MISWMP [12]. In this context, the search for a better allocation of the solid waste already generated [21] goes through the analysis of the management and waste management adopted in the city, through the MISWMP and the strategies used in the waste production chain, including their disposal.

The C&D management system of the municipality of Belo Horizonte consists of thirty-four URPV, two ERE in the city and one landfill located in the metropolitan region. ERE and landfill serve the large generators that, through the C&D transport companies, discharge their normally conditioned waste in buckets. URPV are used to supply small generators, with a maximum daily generation of 1m³ of waste, in order to minimize irregular deposition. The C&D flowchart from the existing municipal waste management structure is presented in Fig. 3.

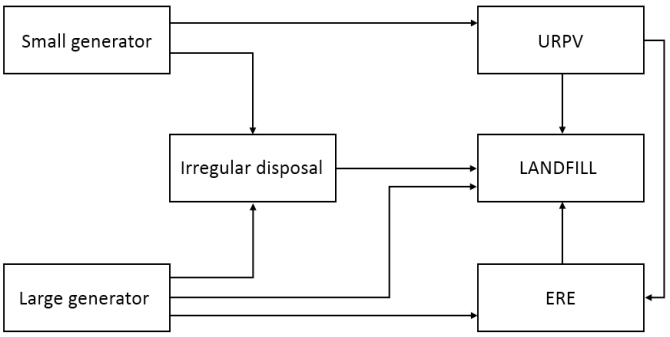

Fig. 3. Flowchart of C&D management in the city of Belo Horizonte. Adapted from [14]

The objective of this topic is to present an overview of the reception areas of Construction and Demolition Waste (C&D) in the city of Belo Horizonte.

1) Units for receiving small volumes (URPV)

URPV are public facilities to receive C&D, pruning and land waste, up to the daily limit of 1m³ per trip, as well as tires, mattresses and old furniture [14].

According to the SLU there are thirty-four URPV distributed in the nine regional cities. The materials are received in the URPV in buckets and, after sorting, part of the waste goes to the landfill and another parcel to one of the two ERE present in Belo Horizonte, where the waste is recycled and reintroduced in the construction chain civil society [14].

Fig. 4 presents the quantitative URPV of Belo Horizonte by regional, as well as their spatial distribution in mapping performed in ArcGIS software.

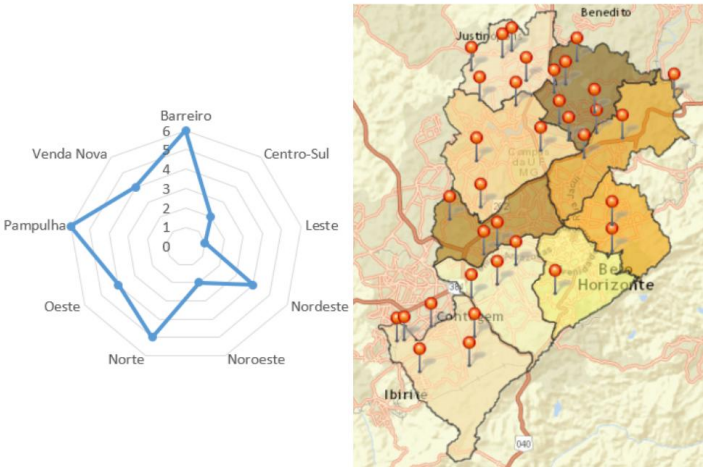

Fig. 4. (a) URPV by regional (b) Spatial distribution of URPV. Adapted from [14]

According to the annual reports (between 2007 and 2013), total waste received in the URPV was 114,347 t/year (annual average of the period). It is estimated quantitative of 130,650 t/year for the 2017 [12]. The total C&D received in the URPV, per year, is presented in Fig. 5, according to [22].

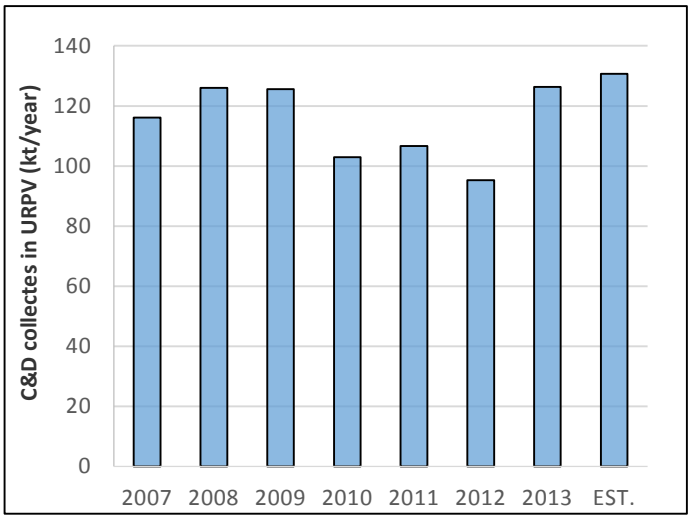

Fig. 5. Quantitative C&D received in the URPV between 2007 and 2013. Adapted from [22]. *EST. - ESTIMATED FOR 2017 [12]*

URPV, although their spatial distribution is heterogeneous in the city, are important structures to reduce the occurrence of irregular depositions. The expansion of URPV in cities such as Belo Horizonte, however, faces, as limiting factors, mainly restrictions on land use, the existence of few public lands available and the population's aversion to the installation of URPV in the neighborhood (NIMBY - "Not in My Backyard" [23]). In addition, deployment and operational costs limit the expansion of this important public equipment in C&D capture.

2) Stations for rubble recycling (ERE)

The use of waste as raw material in construction helps reduce the amount of natural resources taken from the environment. The residues studied could become a great help in the production of alternative materials of lower cost, replacing to a large extent the natural aggregates used in concretes, mortars, blocks, containment barriers, paving layers and other applications [24]. Researches using Construction and Demolition Waste (C&D) have already been carried out in Brazil and the world for different applications, as shown in Table IV.

In this way, the proper management and recycling of waste are beneficial to the environment, since they lead to a decrease in the consumption of natural resources and the volume of waste sent for disposal [25]. According to [26], the MSW management is currently a major concern for city authorities and planners due to population growth, urbanization and limited land space.

The ERE are equipment for the reception and recycling of C&D, produced by large generators, which use trucks or buckets as means of transport. Residuals from civil construction produced by small generators are received at the URPV and, if properly segregated, are transported to the recycling plants [14]. Data from [12] indicate that only 5% of the waste collected in the URPV is sent to the ERE for recycling.

TABLE IV
RESEARCH USING C&D IN BRAZIL AND WORLDWIDE

Title	Country	Author
Use of Recycled Construction and Demolition Waste Aggregate for Road Course Surfacing	Spain	Herrador et al. (2011) [27]
Resilient moduli response of Recycled Construction and Demolition materials in pavement subbase applications	United States	Arulrajah et al. (2013) [28]
Analysis of the effects of adding lime on construction and demolition waste for use in paving	Brazil	Ceolin (2015) [29]
Laboratory evaluation of the use of cement-treated construction and demolition materials in pavement	Australia	Mohammadinia et al. (2015) [30]
Use of recycled aggregates from construction and demolition waste in geotechnical applications: A literature review	Portugal	Cardoso et al. (2016) [31]
Performance evaluation of recycled asphalt mixtures by construction and demolition waste materials	Iran	Fatemi e Imaninasab (2016) [32]
Recycled plastic granules and demolition wastes as construction materials	Thailand	Arulrajah et al. (2017) [33]
Particle breakage in Construction Waste (CW) induced by compaction	Brazil	Silva et al. (2018) [34]

PBH and SLU implemented the rubble recycling program in the late 1990s to transform C&D into recycled aggregates. The first unit inaugurated in the Estoril neighborhood (1995) was disabled in 2013 due to the impact on the neighborhood (reaffirming the difficulties inherent in NIMBY). After this deadline, the community again mobilized, demanding the closure of the unit. The lack of adequate public land prevented the resettlement of this unit. Currently, there are two ERE in operation: the Pampulha unit (inaugurated in 1996 and located in the regional of the same name) and CTRS BR-040 (inaugurated in 2006 in the regional Noroeste).

The segregated C&D, delivered to one of the ERE, are transformed into a recycled aggregate, which can be reintroduced into the building chain, replacing the natural sand or gravel. According to [14], the ERE located in the Noroeste regional has a nominal capacity of 80 t/hour, while that of the Pampulha unit is 30 t/hour. Fig. 6 shows the recycling station located in the Pampulha regional [15].

3) Irregular disposition and landfill

Data from Belo Horizonte prefecture [35] indicated that the city had about 650 irregular waste depositions, although there is legislation to inhibit the inadequate disposal of Construction and Demolition Waste (C&D). Routing of solid waste to inadequate sites is one of the worst impacts on the environment, since the decomposition of the materials generates highly toxic substances that directly contaminate the soil, water, air, fauna, flora and human population. It is an illegal practice whose damaging effects are not controllable and, over the years, presents increasing costs for adopting control measures [36].

Fig. 6. Recycling station located in the Pampulha regional

According to [12], illicit deposition generates an expense for the Municipality of about US$ 39 millions per year (considering the average dollar quotation in May/2018), with the collection and landing of this waste. Estimates in the abovementioned management plan quantify 114,000 tons of irregularly disposed waste in the year in question. It is possible to check the Environmental Police inspection [35], which verified the inadequate deposition of solid waste near the river Das Velhas (Fig. 7).

Fig. 7. Irregular deposition near the river Das Velhas

There are studies carried out in the Brazilian cities of Passo Fundo - RS [2], Parnaíba - PI [37], São José do Rio Preto - SP [38]; Uberlândia - MG [39]; [40] and São Paulo - SP [41] that relate the incorrect deposition of solid wastes to different environmental, social and economic aspects. The main aspects cited in these studies related to the irregular waste deposition were poor inspection and management, as well as accessibility to the deposition points.

In order to identify areas of solid waste deposition, environmental, social and economic factors must be met [42], [43], and their management is a challenging task for many developing countries [44].

In this way, the influence of the spatial distribution of the URPV in the city in relation to the residues collected by the city hall in irregular depositions, constituted mainly by C&D, can be perceived. These findings confirm the need to review the structure of the URPV and direct the decision making for the installation of new units, with a more homogeneous distribution.

IV. CONCLUSION

The main objective of this research was to present the panorama of the current areas of disposal of Construction and Demolition Waste (C&D) to evaluate the management of waste generated in Belo Horizonte. In this way, it was presented basic information about the municipality, the analysis of the generation and possible allocations of C&D and a diagnosis of the public equipment involved in the management of this waste of the city.

In relation to the basic data about Belo Horizonte it is shown that the municipality presents nine regional with population distribution and heterogeneous areas, being the Noroeste region the most populous and the regional Barreiro with the largest territorial area. Residuals generated in the municipality show a high level of C&D collected in the URPV, in irregular locations and by private and public emitters (32.3% of the total solid waste collected in the city).

Regarding the analysis of generation and destination of the C&D, we tried to conceptualize the origin of the residues coming from the civil construction. As well as, to present the classification of the C&D typology, according to the CONAMA Resolution no. 307/2002, and the possible destinations of the same. It is concluded that the situation that generates greater reuse of C&D and less impact to the environment is the recycling of C&D Class A and B.

The diagnosis of the public equipment involved in the management of C&D in the city of Belo Horizonte indicates positive aspects and failures. Although the city has a good structure, in accordance with the requirements of CONAMA Resolution, the operation of these structures needs improvement. Regarding URPV, it was observed that the facilities are distributed in a heterogeneous way in the municipality, with places with a higher concentration of URPV in relation to other sites, influencing irregular depositions. In addition, about 95% of the waste collected in the URPV is destined for landing, indicating that, although the units are able to aid in the reduction of irregular depositions, they are not acting in their function of sorting the material received.

Regarding recycling, it was possible to notice that, despite the good structure provided by the city, through its ERE, there is a low utilization of the facilities. Of all the C&D generated in the municipality only 12.3% (49,839.24 tons) were sent to its reuse. In addition, ERE operate most of the time below installed capacity (from 80 t/hour and 30 t/hour, respectively for Noroeste and Pampulha ERE).

Finally, it is concluded that the management of the areas of reception of Construction and Demolition Waste (C&D) in the city of Belo Horizonte requires government intervention and greater performance of the managers. Although existing public

facilities have a good structure, it is necessary to optimize the available resources, as well as to obtain greater participation of the population in the correct disposal of C&D. In order to achieve this objective, it is suggested the implementation of incentive and environmental education programs in the municipality for the correct disposal and reuse of the C&D generated. In addition, the expansion of inspection and application of fines to waste generators may contribute to the correct disposal and reuse of the generated RCDs.

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