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Management of Waste from Packaging of Construction Materials in Building Construction Works

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Abstract: Every material arriving at the construction site comes protected in some type of packaging, fundamentally cardboard, plastic or wood, and presently the great majority of these packagings finish in a container mixed with the rest of waste of the construction work.

The increasing tendency to use prefabricated materials increases the volume of packaging necessary in product transport; in addition, the traditional materials also arrive more protected with packaging. A specific management for this kind of waste is analyzed on this article.

The main problem packaging implies in a construction work is the volume it occupies; in the case of the plastic, the construction of a block of 100 houses generates more than 1,700 m^3 of plastic waste, basically film to wrap the pallets, and a weight of 35 kg. This means that if traditional containers are used, these will transport a great amount of air.

Recommendations for the management of the waste coming from plastics packaging includes the segregation at origin, trying to maintain the product packed until the last moment and immediately storing the packaging material once it has been opened. When there is space enough at the work site, containers of greater dimensions than the traditional ones can be used. These containers will be only for discarded plastic materials, and at the same time, compactors can be used to reduce the volume of plastics. Finally, once the container is filled up with the specific waste, it will be managed by an authorized valorizing agent, indicating the waste nature.

Keywords: Waste, Packaging, Construction Materials, Segregation**.**

1. INTRODUCTION

The generation of waste coming from construction sites in the last years has reached a volume that claims the importance of a correct management as a widely recognized fact. However, the present management of Construction and Demolition Waste (CDW) focuses basically on the inert waste such as concrete, aggregate, ceramic materials etc.

Until now, special interest in packaging waste from material protection or transporting has not been observed; although, in some works, different types of containers for different types of waste can be seen.

In order to analyze the regulations regarding packaging of construction materials and their management, the study undertaken unfolds in a double approach: waste related to construction and waste coming from packaging.

This research has the following main aims:

1. To successfully obtain and analyze the standard and existing documentation in relation to the management of waste coming from packaging in a construction work.
2. To quantify the volume of waste packaging implies, its composition, and the phases of the construction work during which they are generated.
3. To analyze the real waste management carried out presently by constructors, and
4. With the different materials that constitute the common packaging in a construction work already classified, and knowing its volume, to raise possibilities of optimizing its management by following the recommendations to correct and improve the present practices.

The legal regime of construction and demolition waste in Spain refers to the Law 10/1998 on waste, which defines "waste" as any substance or object included in one of the categories that appear in the attached document of this Law, and which the owner has to dispose. In any case, it indicates that materials in the European Waste Catalogue (EWC), approved by the European Institutions, are the ones that will have this consideration.

The 10/98 Law limits the competence of local bodies on waste and rubble originated from minor home repairs and construction works, leaving the competence for the rest of construction and demolition waste to their owners, who are forced to manage it on their own or deliver them to a waste manager to be recovered or disposed.

Within this construction and demolition waste framework, a later Royal Decree 1481 / 2001 regulating waste disposal through the deposit in landfills and dumps has come into force. In addition, two National Plans on construction and demolition waste have been developed, which specify short, medium and long term objectives, and in Madrid Region an Integrated management of construction and demolition waste Plan has been ensured [1].

At the European level, the order of the Ministry of environment 304/2002 published the so-called list or

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European Waste Catalogue (EWC), where Chapter 17 corresponds with "Waste from construction and demolition (including the excavated earth in polluted areas)". Within this list, in paragraph 2 "Wood, glass and plastic" are included. Chapter 15 includes packaging waste, with containers of paper and cardboard, plastic, wood and metal.

European legislation regulating the production and management of construction and demolition waste is included in the 2006/12/EC Directive of April 5th [2]. This standard aims to create a framework establishing targets as a basis to promote specific legislation on the matter.

The basis for waste packaging recycling and recovery are marked by Directive 94/62/EC of the European Parliament and of the European Council on packaging, and packaging waste [3, 4]. In the field of construction in Spain, various initiatives have been developed to improve the management of inert waste, but no documentation has been found focussing specifically on the waste created by packaging of building materials. Those materials are mainly wood, cardboard and plastic. There are only general recommendations present in the Manual of minimizing and management of construction and demolition waste, published by the Institute of Construction Technology of Catalonia [5], within the framework of the program Life of the Directorate General of environment - European Commission, in which a brief chapter is dedicated to packaging and plastics.

When determining responsibilities for the management of packaging waste, the regulations distinguish between the container, which is necessary for handling the product and the non-essential packaging; in the first case, the manufacturer or distributor of the product is the responsible person, and in the second case, the holder of the product is responsible for it.

The work developed by the Building Research Establishment (BRE) is to be highlighted [6]. Its content has a close relation with the survey performed here, as well as being a solid and well argued study. The methodology used relies on the tool called “SMARTAudit” and is used to quantify and categorize waste by source, type, number, cause, and cost [7].

This requires an observer in the construction work to measure the waste, and present the results in terms of volume. The BRE observer is trained to measure the volume of the waste, the length, width and depth of each product in the container and once the volume is obtained a coefficient is applied from a table of densities of the study --depending on the material-- to obtain the weight.

Data for the study of the BRE is therefore collected through observation of the on site containers, making 5 rounds per day. However, it seems difficult to ensure that the same waste is not measured twice or conversely, some waste may be hidden and not accounted for.

The proposed work is based on an initial theoretical study performed that analyzed the type of packaging protecting each material used in three building construction works. It later develops a fieldwork through the collection of samples of each type of packaging to weigh them and measure them. In this way, real weights and volumes for each group of packaging are obtained, instead of relying on a more or less precise measurement of materials discarded in the containers, and therefore already contaminated with other remains.

2. MATERIALS AND METHODOLOGY

The main objectives of this research are as follows:

To study and describe the real management carried out in the construction works by analyzing the delivery notes from the densities in the waste containers made by the waste management agent, and relating them to the construction period when they were submitted. This is done to obtain a descriptive evolution of the generation of waste during the construction work, and its overall quantification. The final cost will be added to the management by an authorized evaluator.

To establish the volume of packaging materials on the construction work site, distinguishing among cardboard/ paper, plastic and wood. A descriptive evolution along the construction work for each of the materials will be established and will be compared to the earlier planning of the work.

To contact authorized evaluators to analyse the possibilities of the material packaging management obtained from the construction work, by applying economic data to the specific work, so as to obtain the final cost with a management based on the separation and sorting at source

To compare the economic results of the real management and the proposed one.

To summarize a series of recommendations applied to the management of packaging waste in building works.

In order to achieve these objectives the research will be based on the following data:

Supplies information:

Data available from the construction company purchases for all the materials involved in each work will be analyzed, and introduced in Presto format in two major chapters: "Purchases" and "Industrial supplies", depending on whether the material provider is a primary supplier or a subcontractor.

Data on CDW:

Data of the construction waste from the supplier of the on site containers will be processed together with data from the authorized waste manager from Madrid’s region. The delivery note of each container includes volumes, weights, densities and composition of the waste generated during the construction work, including the generation date.

Planning of the works in Microsoft Project.

Planning will be used to determine when each material is used during the course of the construction work, and therefore, when the corresponding packaging waste is generated.

The methodology of the work comprises three phases:

Detailed theoretical study of the construction work:

The purchasing data is broken down for each material type of packaging present in the construction site, quanti-

fying the number of packaging units based on measuring each construction chapter.

Field study:

Samples of each type of packaging found in the preceding paragraph will be collected, to check their weight and volume. All these data will be introduced in a table where weights and volumes of each of the packaging protecting the materials will be quantified, to finally group them into three groups: paper/cardboard, plastic and wood.

Analysis of the data from the containers:

Data obtained from the company managing the RCD are to be analyzed, relating them in time, so that graphics can be obtained to show a descriptive evolution of the total volume of waste throughout the construction work.

Establishing a relation between the detailed study of the packaging volumes and the construction work planning will allow determining the stages where higher volumes of packaging are produced. Finally, the indicated data with the real data of the used containers and densities will be compared to check if they are related.

Almost all products arriving to a construction work site are protected by packaging material, which can be classified into three categories:

- Primary packaging that contains and protects the goods.
- Secondary packaging, grouping together a number of products.
- Transport packages, protecting the object during transportation.

The main packaging materials are paper, cardboard, plastic and wood, all of which represent a large amount of material to be collected and reused, recycled or recovered from construction sites.

The construction works chosen for the study are mid-sized housing blocks, with samples in blocks of 100, 118 and 112 houses (called "CONSTRUCTION WORK 1, 2 and 3" respectively).

The so-called CONSTRUCTION WORK 1 consists of a 100 social housing project, storage areas and garages with a total built area of 15.065,51 m2, 7 floors above ground and 1 under ground level.

CONSTRUCTION WORK 2 consists of 118 dwellings, commercial premises, storage areas and garages with a total built area of 19.211,80 m2, 5 floors above ground level and 3 under ground levels.

CONSTRUCTION WORK 3 includes 112 homes, storerooms and garages with a total built area of 15.065,51 m2, 6 floors above ground and 2 under ground level.

3. RESULTS AND DISCUSSION

Descriptive evolution of waste: an examination of when each kind of waste is produced is performed to establish a relationship between the weight of the waste and the period of the work in which it is produced. This will help to determine the phases of the work in which the largest amount of packaging waste is generated, and when the appropriate time is to introduce equipment that allows optimizing its management.

In order to establish a chronology of the waste management plan, the construction work planning will be used as the basic pattern. By using it, the moment each waste product is produced can be established. Subsequently, density data from the containers is analyzed, knowing at the same time the moment of the construction work when it has been produced.

Fig. (**1**) shows the descriptive evolution of the volume of cardboard waste of the three works, and Fig. (**2**) reflects the evolution of cardboard in weight

CONSTRUCTION WORK 1

CARDBOARD	2,887.36 kg	67.31 m^3

CONSTRUCTION WORK 2

CARDBOARD	4,039.33 kg	88.25 m^3

CONSTRUCTION WORK 3

CARDBOARD	4,823.45 kg	71.15 m^3

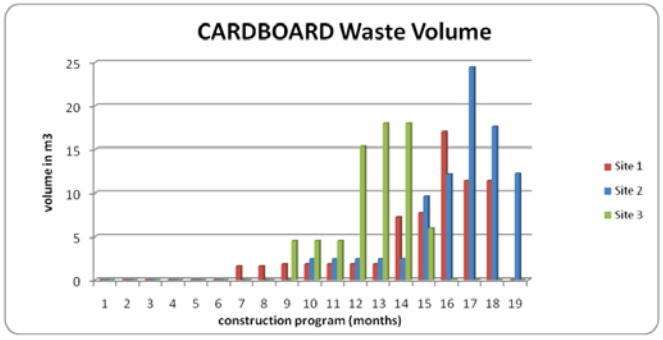

Fig. (1). "Descriptive evolution of cardboard waste volume".

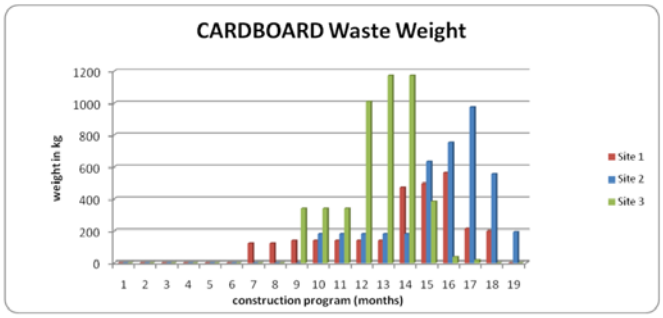

Fig. (2). "Desciptive evolution of cardboard waste weight".

The descriptive evolution of the volume of plastic waste of the three construction works can be seen in Figs. (**3** and **4**) reflects the evolution of plastic in weight:

CONSTRUCITON WORK 1

PLASTIC	1,691.71 kg	34.73 m^3

CONSTRUCTION WORK 2

PLASTIC	2,320.35 kg	46.25 m^3

CONSTRUCTION WORK 3

PLASTIC	2,236.54 kg	42.59 m^3

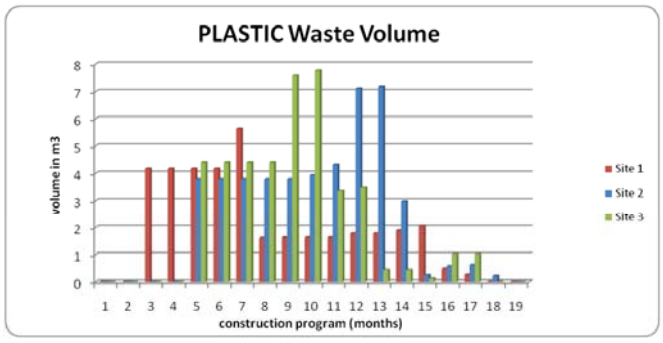

Fig. (3). "Descriptive evolution of plastic waste volume".

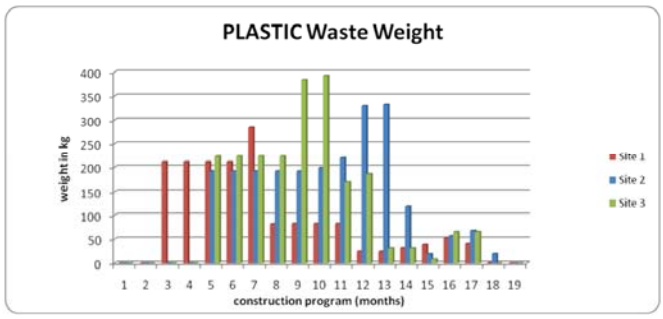

Fig. (4). "Descriptive evolution of plastic waste weight".

Analysis of the graphs obtained in the preceding section shows different results, depending on each type of packaging:

Cardboard and paper (Figs. **1** and **2**) appear in the second half of the construction work, reaching the greatest quantities during the last few months. This is so, because the materials that cause greater amount of cardboard packaging are ceramic claddings, sanitary fittings, fittings of woodwork fittings and electricity mechanisms. All these are fitted or installed when the masonry works are finished and during the last months of work.

Plastic (Figs. **3** and **4**) comes primarily from film sheets of pallets, and this is a material used in the majority of products supplied in pallets. Therefore, the volume of plastic waste shows similarities with that of wood waste. The first great generator of plastic waste are the one-way slabs, which makes plastic waste appear from the beginning of the building and it continues to be generated with the brick pallets and other materials that are supplied in pallets, until a few months before the end of the construction, when the predominant packaging becomes cardboard.

The descriptive evolution of the volume of wood waste of three construction works can be seen in Fig. (**5** and **6**) reflects the evolution of wood waste in weight.

Wood (Figs **5** and **6**) evolves in a similar way to plastic, because both are associated to pallets, as has already been said. Due to its nature, wood is the main material in terms of weight of all packaging occurring in the construction work, given that its density is much greater than that of cardboard and plastic.

CONSTRUCTION WORK 1

WOOD	74,832.85kg	958.58 m^3

CONSTRUCTION WORK 2

WOOD	104,457.24 kg	1,225.47 m^3

CONSTRUCTION WORK 3

WOOD	99,823.66 kg	1,167.94m^3

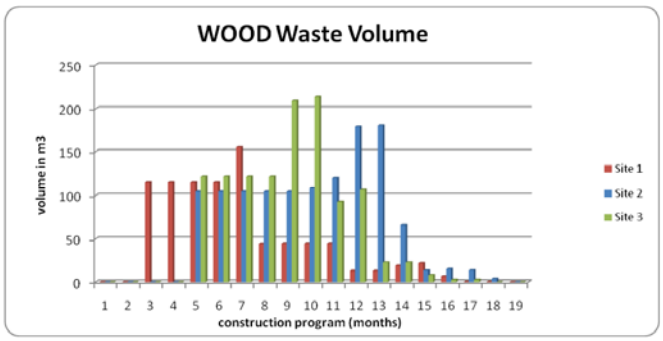

Fig. (5). "Descriptive evolution of wood waste volume".

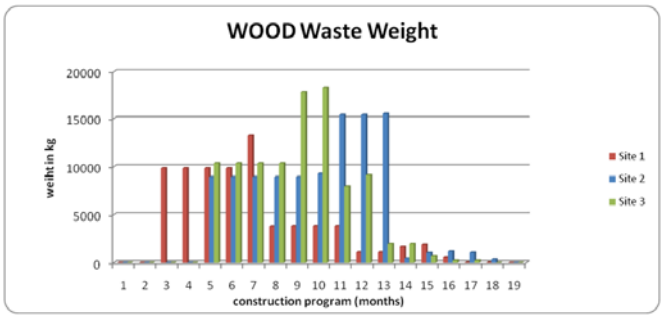

Fig. (6). "Descriptive evolution of wood waste weight".

The results of the two other works studied were relatively similar, although it can be seen that in CONSTRUCTION WORK 1 the volume of packaging is more distributed during the period of construction than in works 2 and 3. In the latter ones, a greater concentration in the central months is observed. This is so because the first construction work has the homes distributed in three blocks, while the other two construction works have all dwellings concentrated in a single housing block building.

Trades, which generate more packaging, are more widely spread among the three stages of the first construction work than in the other two ones. In the two last ones the waste generation pace is more concentrated. Works with a single building, rather than staggering phases require the end of the structure chapter to begin the masonry works, coatings etc. This causes that in the three building construction work the generation of packaging is small but steady from the early stages on, while in the construction of a single block the volume of packaging waste accumulates more during the central months.

Results obtained in the previous section, are shown in a graph summary (Figs **7** and **8**) with the total packaging waste in terms of volume and weight.

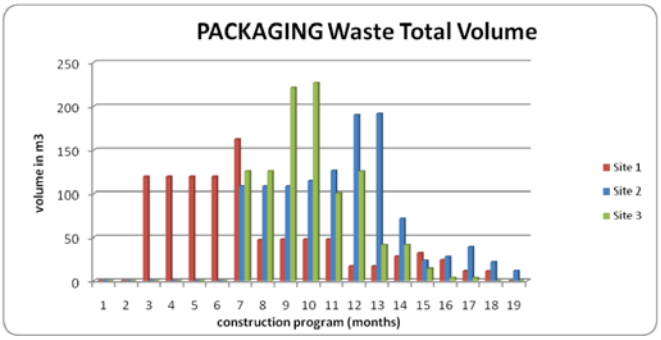

Fig. (7). Descriptive evolution of total packaging waste in volume.

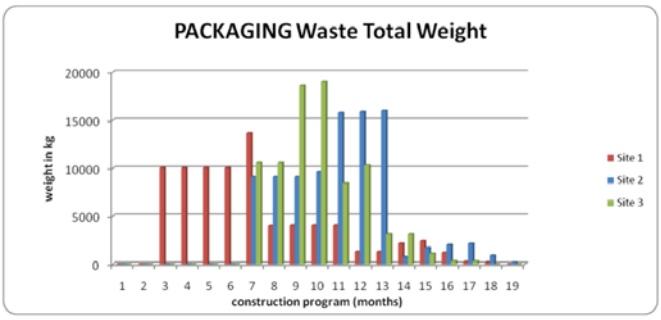

Fig. (8). Descriptive evolution of total packaging waste in weight.

The total waste volume from CONSTRUCTION WORK 1 was 2.534 m^3. This provides data on the weight of the container on arrival to the plant of 57% of the trucks; data, which allows obtaining an average density of the container, content of 0.678 tons/m^3 and an average weight of 895.44 tons.

Using a table to summarize the distribution of the containers in the months of the construction work, a graph (Fig. **9**) is obtained with the distribution of densities for the time of the construction work. This figure shows certain parallelisms with the two previous graphs.

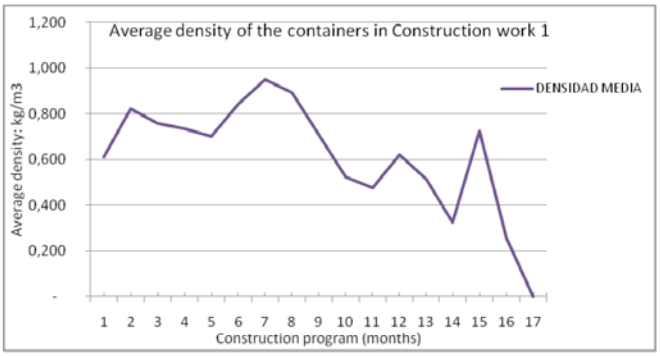

Fig. (9). Average density of the containers in CONSTRUCTION WORK 1.

The ratios obtained from theoretical volume of packaging and built surface throughout the three construction works analyzed is uniform, with an average of 0.068 m^3/m^2.

Table **1** below shows the total Construction and Demolition Waste from CONSTRUCTION WORK1, although as it has been indicated, the ratios of the three samples were quite homogeneous.

Table 1. "CDW Volumes/Built Surface Ratios"

CONSTRUCTION WORK 1: Construction Waste		
TYPE	WEIGHT (Tn)	VOLUME (m^3)
Total PACKAGING	**79.41**	**1,060.61**
mixed CDW Containers (m^3)		**2,534.00**
RATIOS (M^2)	m^3RDC/m^2	m^3 EMB/m^2
	0,1682	0,0704

If a relation between the actual ratio of mixed CDW with the ratio of packaging waste is made, the volume of packaging waste within the total CDW is 43.6 per cent. However, bearing in mind that not 100% of the packaging

Table 2. "Summary of the Costs Regarding the Two Types of CDW Management"

CONSTRUCTION WORK 1: CDW Costs					
	Total volume	Container volume	Nº of containers	Container price	Total cost
Mixed CD	2,534.00	6.00	379.00	107	40,553
Wood		22.00	8.00	107	856
TOTAL MIXED CDW MANAGEMENT					**41,409**
Cardboard	67.31	22.00	3.00	107	321
Plastic	34.73	22.00	2.00	107	214
Wood	958.58	22.00	44.00	107	4,708
TOTAL EMBALAJES					**5,243**
mixed CDW rest	1,473.39	6,00	245,56	107	26,275
TOTAL CDW MANAGEMENT SEGREGATING PACKAGING					**31,518**
Difrence between the two types of CDW management					9,891

was considered but only approximately 70%, it can be estimated that all packaging waste in this kind of work can reach 50%.

Regarding the economic difference from the traditional management of CDW and the proposal with packaging segregation, the results (Table **2**) show savings ranging between 25-30% in favour of the differentiated management.

4. CONCLUSION

In contrast to the increasingly widespread environmental policies, it can be proved that products supplied to the construction work nowadays have suffered an increase in the volume of their packaging, to improve their level of protection and reduce their return percentage.

Transferring this fact to brick for example, in a construction work of 100 homes in one block, a generation of more than 400 kg of film for brick pallets is implied. This material however, until a few years ago had been moved and supplied on pallets and held with straps, using no plastic film.

From the results obtained, there is no doubt that differentiated packaging waste management is a need, and this is justified on two contrasting facts:

Packages represent 50% of the volume of CDW in a construction work. The materials constituting the packaging are recyclable.

Today, with the exception of the wooden pallets, the other packaging composed of cardboard and plastic generated in a construction work will go to a dump, increasing costs in the form of management fees which are not justified. At the same time, this waste occupies a space, which should only be used for non-recyclable waste, and never for recyclable materials.

A construction work should begin by raising awareness within the agents intervening in the construction, especially among the workers, to make them partakers of the importance of the segregation of waste at source, with the double objective of saving money for their companies and causing less damage to the environment.

Among the recommendations to be taken into account to optimize the management of the CDW and especially those coming from packaging, as a result of the data analyzed are:

When drawing up the Waste Management Plan, packaging waste should be considered, to calculate the space that will be necessary to place specific containers for waste. A directory of the closest buyers of waste and future recyclers should be prepared.

In works were the dimensions make it possible, a space for containers of cardboard, plastic and wood, should be provided, and these should be adequately marked by colour codes to avoid dumps in them of any different material from the expected one.

Products supplied on site should not be unwrapped until the moment they are going to be used, and in this way, a double objective will be achieved to maintain the product in better conditions, and not to damage the packaging.

Since, as it has been shown, plastic and wood are fundamentally linked to pallets, plastic and wooden containers should be placed in a place that facilitate the unpacking of the product, and where the pallet plastic film, and the pallet itself, can be deposited in their respective containers. At the same time, the placing should ensure the direct collection from the unpacked product by the crane to move the material to the place where it will be used.

On the contrary, the cardboard container does not require a specific place as seen in previous sections. Materials that are protected by cardboard can be unpacked at the place where they are going to be used. In the places where works are performed using products packed in cardboard, such as ceramics, fittings, carpentry or electrical mechanisms, they should have small containers to collect the empty boxes and cardboard remains to avoid mixing them with the rest of the waste. before they are taken to the corresponding container.

The construction staff should receive a minimum training on waste management, explaining the reasons for which a segregation of packaging materials is going to be carried out and giving simple performance measures with these waste.

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CONFLICT OF INTEREST

None declared.

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