Evaluation of Waste Generation in a Housing Construction Work to Develop Improvements in its Final Disposal

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Abstract. Construction is one of the productive sectors that generates the greatest environmental impact, on the one hand, there are high demands for raw materials and energy required for production, and on the other hand the large amount of solid waste is generated. In Chile, construction waste management is becoming a problem mainly due to the lack of planning for proper final waste management, wasting potentially reusable, recyclable or recoverable material. Knowing how to manage construction and demolition waste contributes to improving quality and production in construction work as well as maintain a responsible attitude towards the environment. This research study seeks to evaluate waste generation in a residential building work, to deliver proposals for improvements in the final disposal of these, through the creation of a methodology to quantify the waste production. In conclusion, submitting proposals for improvements for the implementation of a waste management system helps to achieve an activity within the construction sector, whose main objective is to contribute to a more sustainable construction through an adequate final disposal of waste generated in the construction process.

1. Introduction

The construction represents a fundamental sector for the economic progress of the countries achieving a great contribution to the productive development, however, it is an activity that demands important natural resources such as energy, water and raw materials, generating high rates of construction waste produced worldwide, a category that represents more than a third of the world's solid waste. [1].

The production of construction waste (RESCON term derived by the National Commission of the Environment) generates an environmental problem due to the increase in volume of waste generation and its treatment, which is unsatisfactory in most cases. The choice of materials from the design phase is a priority to reduce the future construction environmental impact. [2]. This requires knowledge, in detail about the volume and type of waste generated during the life of construction.

As a result, professionals in the area are being designed to promote the effective management of RESCON, through the 3R principle; reduce, reuse and Recycle. [3]. Moreover, the implementation for this management is challenged by the perception that is delays the activities progress of the new construction, making it low priority practice compared to other project goals during the new construction, such as meeting the project deadline and profit maximization. [4] [5] [6].

Poor prevention to reduce waste joins in with the non-recycling item. Some of the negative environmental impacts are soil contamination, aquifers in rubbish dumps, landscape deterioration, the layout of road edges, mixed with other waste such as hazardous and urban.

On an international level, the production chain associated with construction items is responsible for:

- 30% of the raw materials used.
- 42% of the energy used.
- 20% of the water used.
- 12% of land use.
- 40% of atmospheric emissions.
- 25% of solid waste.
- 13% of other waste. [7].

The concern about the RESCON growth and its impact on the environment is growing. For this reason, public administrations in many countries are reviewing policies regarding how this waste should be managed.

The panorama of industrialized countries directs their strategic plans towards a comprehensive sustainable management of resources, prioritizing recycling and reusing RESCON; Spain created the State Waste Management Framework Plan 2016-2022, forcing the RESCON producer to prepare a waste management study , [8], however, in other countries like the United States, they face a lack of reliable statistics, [9], in developing countries such as Chile, these activities are mainly focused on Urban Solid Waste. The Netherlands occupies the first place in waste management in Europe, between 85% and 95% of the industrial companies and demolition waste are recycled, there are companies that are dedicated to recycling other waste. Companies are obligated to prevent the generation of such waste. Taxes on sanitary goods were introduced, for those who throw their waste in landfills. It was key to establish the accountability for the producer, by law, so that companies that produce toxic or difficult to treat waste, were forced to design and implement strategies for the final waste disposal. It started with voluntary processes, which are mandatory today. The Netherlands produces 60 million of solid waste per year, 80% is recycled, 18% is incinerated and 2% goes to landfills. [10].

The Chilean construction industry plays a fundamental role in the country's economy, in 2012 it represented 7.2% of the National GDP, increasing to 15.9% in 2015 linked to 2012, [11]. The area has a high demand for energy, materials, labor and technologies.

Construction-related activities are responsible for the development of societies, both for the act of building and for the subsequent use for what they were built.

In Chile, the regulations regarding the disposal of RESCON are scarce since there is no general law or decree that regulates waste management. The regulations in force come from different public bodies which makes compliance and inspection difficult, they only require construction companies to separate hazardous and non-hazardous waste and send them to authorized treatment pants and sanitary landfills. Situation that encourages the construction industry preferably to dispose of waste by depositing it in sanitary landfills, a simple but not sustainable option in parallel does not receive sufficient attention from the authorities and construction managers, mainly due to the lack of RESCON management and treatment plan in the planning stage of a project to reap the potential benefits that could be obtained from them, representing an important barrier to the effective adoption of practices. [12], [13], [14]. In addition to this, on several occasions the waste was disposed of

through unauthorized landfills, which evidences the lack of adequate control, lack of prior controls and subsequent levels of toxicity or degree of recycling.

In 2010, CONAMA conducted the first report on waste management, reporting that in 2009 the generation of solid waste was 16.9 million tons, where 6.5 million tons corresponded to municipal waste and 10.4 million tons to industrial waste.

The construction sector is the largest generator of industrial waste in the country. In 2009, 5.82 million tons of solid waste were generated. [15].

Table 1. Industrial solid waste generation. [3].

Sector	Generation of Solid Industrial Waste (million tons)	Percentage (%)
Agriculture and Forestry	1.56	15
Mining and Quarry	0.63	6
Manufacturing industry	1.83	18
Energy production	0.47	5
Water purification and distribution	0.08	1
Construction	5.82	56

2. Diagnosis of onsite waste management

To perform this study, a prominent construction company in the housing construction area was sought after in the Maule region. Which authorized the entry to work to develop a RESCON generation assessment.

2.1. Practical evaluation of the onsite RESCON generation.

At this stage, the onsite RESCON generation was evaluated, with the obtained data; it is expected to propose efficient practices aimed at reducing the RESCON generation at its source and also sensitize those who are involved in the formation of these, which establishes how a common objective for a work team to reduce the amount of solid waste generated onsite and contribute to a more sustainable construction through an adequate final disposal of the generated RESCON in the construction process.

2.1.1. Identification Source.

First, periodic visits were conducted by monitoring each of the construction processes developed in the housing studied, to identify which items generate waste, then they identified which produced the greatest volume of losses, to distinguish these items the following factors were used:

- Interview of work personnel
- Trade qualification level
- Onsite work
- Level of detail of the constructive item
- Time

2.1.2. Quantification of the generated RESCON.

It was performed with measurement methods and onsite observation, achieving the cubing and modeling of each of the housing items, in conjunction with what was seen on the ground the losses by material were estimated. When performing an analysis of the 5 factors studied and by quantifying them, it was possible to recognize the items that produce a greater amount of waste within the work. The influential items in waste generated are:

- Masonry.
- Overcast and chain molding manufacturing.

- Shingled.
- Waterfront.
- Roof structure construction.
- Poligyp coating.
- Wall plastering.
- Ceramics.
- Partition lining.

Figure 1. Construction waste in the work studied.

This information allowed for a detailed analysis of all the construction items, showing that for most of them the waste generated rates are high, which have not been foreseen, since the construction company does not evaluate the generated RESCON in its projects, "bypassing or minimizing" the losses for unknown reasons, therefore, the emphasis should be placed at this stage, it can prevent and focus professionals on having greater control workers and processes. Due to various reasons, such as the inappropriate use of onsite resources, it is evident that there are greater losses than what should have resulted in greater waste generation and in turn monetary losses.

2.1.3. Final quantification of the generated RESCON.

With the development of the items studied, it is obtained that the volume of waste generated by housing is 14.33 m^3 which are made up of 8.05 m^3 material waste and 6.27 m^3 material packing. The following table shows the ^{total} amount of m^3 generated by material type.

Table 2. The Total RESCON per home.

Material	RESCON m^3
Wood	6.40
Paper and cardboard	1.98
Plastic packaging	1.68
Concrete	1.61
Containers containing hazardous waste	1.33
Insulation materials	0.45
Brick	0.30
Iron and Steel	0.29
Plaster based materials	0.29
Total	14.33

The following graphs show the percentages and classification codes for each RESCON material generated in the items.

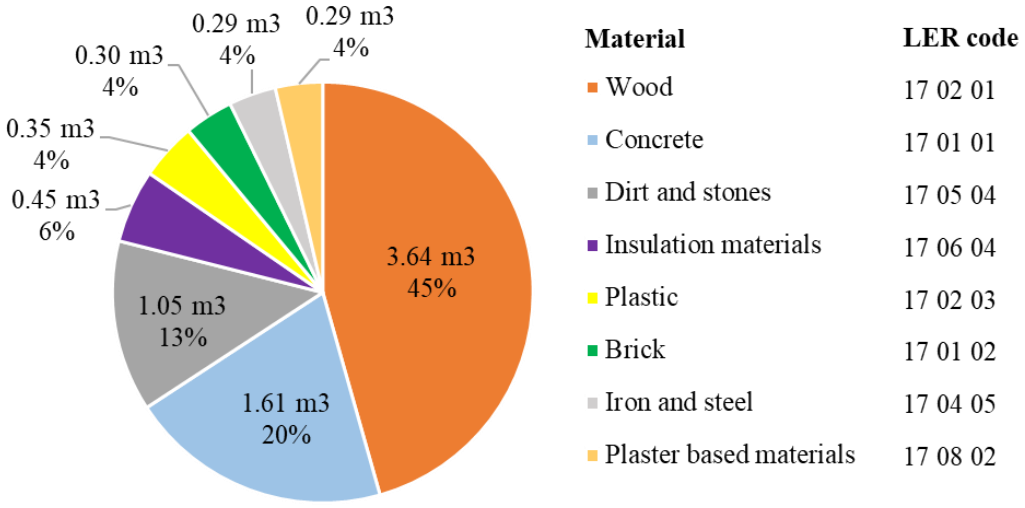

Figure 2. Volume of waste generated by material.

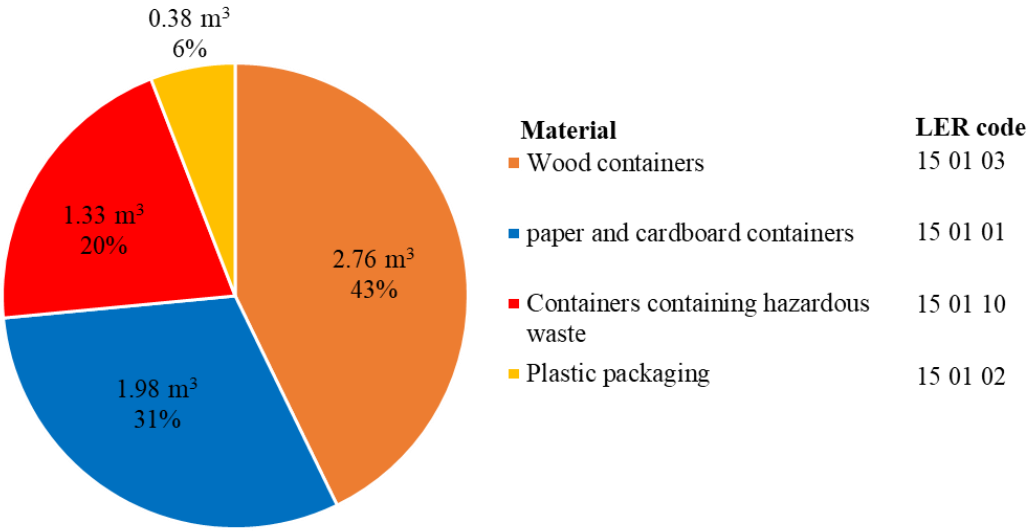

Figure 3. Volume of packaging waste.

The waste of each item was classified according to chapters 15 and 17 of the European Waste List. The list used for the emissions registry and pollutant transfer (PRTR), which obliges waste generating companies to declare the quantities of waste generated by their activities through a form.

The total RESCON generated from homes at the end of the will be approximately 1000 m^3, will be sent in its entirety to an authorized sanitary landfill, being that the only management performed by the construction company which does not allow for the applicability of 3R of the RESCON.

Figure 4. Waste collection area.

3. Proposal for improvements

With the data obtained in the diagnosis considering the characteristics and particularities of the work studied, a proposal for the RESCON management is developed, seeking to implement practices within the work team which entails establishing an appropriate pan for waste management, for this the work must be directly carried out within the work personnel, forming a community that has as a basis to privilege the applicability of the RESCON 3rs. The following measures to prevent waste generation were proposed.

3.1. Projecting the RESCON generation at the design stage

The first estimate at the design stage, project the amount of waste that will be generated during the construction process of the work, providing the information to the technical office of the construction company, to establish a diagnosis of the onsite waste management. Second, mitigation measures may be adopted at this stage to reduce the RESCON, for example, leasing standardized metal parts for framework, this will reduce the losses of the material used in the onsite modeling manufacturing and disposal. Third, to create a waste collection plan that allows the reuse and reduction of waste.

Environmental awareness from the project design stage will allow the construction company to make changes in all its projects reducing waste by managing to execute its project in a more sustainable way.

3.2. Collection Plan

The construction company is proposed to carry out a collection plan that allows to enhance the use of RESCON that can still be used:

1st, identify and separate within the work in mobile containers labeled and painted in a way that facilities reuse and recycle their waste that cannot be used, it is important that such waste is stored just after it is generated in order to prevent it from getting dirty and mixed with other leftovers thus ensuring hygienic and safe conditions within the workplace. This allows the waste to be separated before reaching the waste collection point, facilitating its transport to this area. The containers must be painted and labeled according to NCh3322of2013, clearly specifying what material they will store.

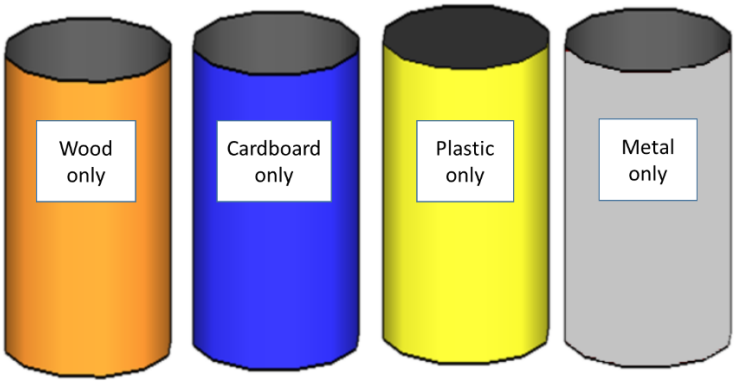

Figure 5. Mobile Containers. Only Wood, Only Cardboard, Only Plastic, Only Metal.

Second, provide a clean storage area for waste collection within the workplace, this area must have containers labeled according to type of waste that can be stored in the area that is occupied by the construction company, labeling the containers with clear and understandable information for all workers, this place should be covered to prevent the waste from getting wet and losing its recoverability.

Third, instruct all staff that it is mandatory to deposit waste in the correct containers according to their labels, it is prohibited to dispose of the waste in other areas that are not the collection area, considering this, at the end of the work day a general cleaning of the work place must be carried out.

3.3. RESCON Valorization

With the study and analysis performed at the workplace, the quantities of wasted generated, the materiality and management of these within the workplace, they are obtained to give way for the realization of its recovery looking for companies that provide recycling services close to the construction site. Thus, buying the waste previously separated in the collection plan. Allowing the reduction of waste volume that is sent to landfill.

Figure 6. Workplace waste.

3.4. Training

Finally, an informative talk was held in which all construction workers participated in order to raise awareness and deliver ideas for improving final waste disposal in the work area. Some of the points discussed were:

- National generation of construction waste.
- Environmental advantages of being a sustainable work.
- Building towards a sustainable culture: reducing the use of resources used and the volume of waste generated.
- Provide information about the obligations that workers have to meet in order to make good management of the construction waste.
- Provide a designated area for the collection of materials.
- Provide information on ways to minimize waste produced in the workplace (recovery, reuse and recycling).

Figure 7. Training.

Informative posters were placed in the dining room and in places attended by all workers, with the aim of informing a more sustainable way of working in the work place, deliver proposals for the complementation of waste management plan and give advice on waste management that could minimize construction waste by giving value to some of them.

Figure 8. Informational Poster.

3.5. Suggested regulations for the RESCON mitigation.

Finally, the construction company is suggested to study the implementation of the following regulations in its activities.

3.5.1. Clean Production Agreement.

It is suggested that in order to perform a Clean Production Agreement to improve the work in order to increase efficiency, productivity, reduce risks and minimize negative impacts on the environment.

Implementing a clean production agreement generally lowers the cost if investment in equipment to be considered from the start of production processes preventing or minimizing the generation of waste and emissions that otherwise should be treated and/or disposed of it. On the other hand, it can reduce the worker's exposure to risk and the number of accidents.

The objective of an industry in the context of clean production is to transform the raw material and inputs into a marketable product or service, minimizing the generation of waste, therefore achieving the highest efficiency of raw materials and inputs used. The generation of waste causes significant economic impacts associated with the treatment costs and the final disposal of these; thus, minimizing its generation has economic benefits for the company. [15].

3.5.2. ISO 14.001

It is suggested to govern their projects through the international standard of environmental management system ISO 14.001, which helps organizations identify, prioritize and manage the environmental risks they generate, as art of their usual practices that promotes environmental protection, through the prevention or mitigation of adverse environmental impact. This standard was designed to be implemented in any organization regardless of size, sector and geographic location. This certification is to improve the way in which the company reduces its impact on the environment, which can create internal benefits by improving the use of resources, for example:

- Reduce the use of raw material and energy.
- Improve waste management.
- Improve efficiency to reduce the operating organizational costs.
- Contribute to the organization's public image.

This standard allows for identifying the environmental aspects and environmental impacts that these generate in their operational process, the environmental aspects are all processes that generate negative or positive environmental impacts to the environmental.

4. Conclusions

Throughout the development of the present study, it was possible to identify that the RESCON management in the work studied, from the moment of its generation until its final disposal, it generates a large amount of environmental impact that should be controlled in order to create an environmentally friendly work place. The main issue of this waste is the improper handling that is given to them onsite, since for the construction company the most important things is complying with the stipulated deadlines for the delivery of works leaving aside the environmental problems that can cause daily execution of their activities.

Thus, the importance of this work is focused on creating an awareness of environmental control in companies in the construction sector by delivering practices for the proper RESCON handling, from their source of origin until their final disposal, since the implementation they will be able to pay attention to the type and amount of waste that they are generating, so that they can cause the least environmental damage, and in turn have an orderly and clean place. Which reduces the accident rate and the good development of its activities.

With the realization of this study, it was possible to conform the current environmental state of construction sectors in the country, which is in an exponential delay with respects to the implementation of environmental laws compared to developed countries, the lack of regulations and adequate oversight of these do not facilitate the reuse, recycling and recovery of waste. There is no regulation governing the management of waste from an environmental point of view.

When quantifying RESCON, it was obtained that the work generated a total of 1000 m^3 when building 70 homes. When the proposal for improvement in a workplace of this type of housing is implemented, it is possible to reduce the volume of waste and final disposal costs by 60.7%, with this the construction budget is reduced and the company contributes to sustainable construction.

For all these reasons, it is necessary for the construction sector makes the commitment to implement improvements in their final waste disposal, making management plans at the project's design stage that reduces and minimizes RESCON generation.

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