# Construction and demolition wastes from residential recuperation

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**Abstract**

In modern society the construction and rehabilitation operation can create a serious environment impacts. These economic activity produce materials define as construction and demolition wastes (CDW). The CDW generated in Europe represents around 25 – 30% of total waste. In EU 28 CDW production is about 821,160 thousand ton, but there is a significant difference between the European countries, mainly because of the variation of construction and demolition activity. In 2011 the total production of CDW in Portugal was about 928.4 thousand ton, but regional production is not homogeneous. The substantial inert fraction from the CDW makes them suitable for reuse. The present study aims to quantify and characterise the CDW from residential recuperation of small constructions in Portugal and then propose mitigating measures to suitable disposal. The results obtained by bibliographic research revealed that the construction and demolition activity has decrease significant in last years and consequently the CDW production. Also it was observed a high number of entities involved in CDW route. So it was necessary to select a specific are from Portugal (Setubal region) with some CDW data for later comparison. The survey sent to the several entities had scarce response. This can be explain by the no obligation to register the CDW from enterprises with less than 10 works and because in some region the CDW are mixed with municipal solid waste.

**Key words:** construction and demolition waste, waste management

## Introduction

In last years, the urban growth has increased, with 54 % of the world's population be located in urban areas in 2014. It is expected that this occurrence continue to grow, estimating in 2050, 66 % of the world's population will be urban. In Europe, about 73 % of its population live in urban areas and is expected by 2050 to be over 80 % (UN 2014). This led to serious problems in the management of urban areas.

Urban growth leads to the need for the construction of new buildings and the conservation of existing with the consequent increase consumption of raw materials, energy and waste generation, including construction and demolition waste.

Unfortunately, the illegal dumping of CDW that occurs routinely and cause environmental problems in cities and surrounding area is a cause for concern (Melo 2011).

Nowadays waste management is a relevant issue to reduce the environmental problems, consumption of raw materials and energy.

Among all the waste produce in EU, the construction and demolition waste (CDW) represents approximately 25% - 30%. In 2004 the CDW production was around 766,000 ton and for 2012 increased to about 821,000 ton in the European countries.

Across the EU there are different CDW definitions, which make difficult the caparison between countries. The CDW comprise waste from distinct activities such as the construction and total or partial demolition of buildings and civil infrastructure, road construction and maintenance (EC, 2015).

According to information presented in the Eurostat (2015) CDW production varies significantly from country to country. The per capita value ranged from 4 (Latvia) to 13,334

(Luxembourg) kg.inhab$^{-1}$.year$^{-1}$ and EU 28 medium value was 1,627 kg.inhab$^{-1}$.year$^{-1}$ (Eurostat, 2015). This can be explained by several factors like economy, development level and different CDW definition.

The CDW issue has been widely debated, leading to the development of environmentally sustainable solutions. In this context, European environmental legislation has become more rigorous, with a tendency to make producers responsible for their own waste and adopting waste minimization and recycling measures.

Several European legislation has been adopted to the general waste management and list of waste (Directive 2008/98/EC, Commission Regulation (EU) No 1357/2014, Decision 2000/532/EC and Commission Decision (EU) No 2014/955/EU). The waste management concepts, definitions and management principles such as the "polluter pays principle" or the "waste hierarchy" are presented in Directive 2008/98/EC (EC 2015).

Nowadays, the CDW is a stream waste according with the European List of Waste (Commission Decision 2000/532/EC, Commission Regulation (EU) No 1357/2014, Commission Decision (EU) No 2014/955/EU) and the Portuguese legislation (ordinance n. 209/2004), which attributed the following chapter “17 – Construction and demolition wastes (including excavated soil from contaminated sites)”. The chapter 17 is divided in several sub-categories to create the full waste code defined by the six-digit (Table 1).

Table 1

The CDW comprises several materials, concrete (17 01 01), bricks (17 01 02), gypsum (17 08 XX), wood (17 02 01), glass (17 02 02), metals, plastic, solvents, asbestos and excavated soil and also some waste with hazardous substances (Annex III to Directive 2008/98/EC, Commission Regulation (EU) No 1357/2014) like mercury, PCB. In that case the code is defined by the six-digit and a "*".

The CDW is a priority waste stream because has high potential for recycling and re-use, with possible resource value. Although the technology for CDW separation and recovery is available with no significant costs, the level of recycling and re-use in EU varies from less than 10% to over 90% (EC, 2011). The Waste Frame Directive (2008/98/EC) stipulates a minimum of 70% (by weight) for re-use, recycling and other material recovery (including backfilling) for each Member States.

The CDW production is divided in six sectors: residential construction; non-residential construction; residential demolition; non-residential demolition; residential recuperation; and non-residential recuperation (Mália, 2010).

According to Melo (2011) the urban construction activity in Portugal from 1997 to 2007 increased until 2002, in terms of the highest number of buildings and the largest surface area completed. After 2002 there was a decrease in construction activity.

In a study from 2002 for the Littoral North of Portugal a CDW production of 2,132,600 ton.year$^{-1}$ was estimated from the value per capita 325 kg.inhab$^{-1}$.year$^{-1}$ (Pereira 2002). This value was obtained from a study realised for rural and urban regions from Spain. Therefore, real numbers are difficult to obtained (Mália, 2010).

In Portugal the CDW per capita value in 2004 was 1,090 kg.inhab$^{-1}$.year$^{-1}$ (EC 2011), but according Eurostat (2015) for the same year the estimated value was 250 kg.inhab$^{-1}$.year$^{-1}$. In 2006, the CDW production was estimate in 4,425,157 ton (Coelho and Brito, 2013), which was calculated from a regional study for the Lisbon Metropolitan Area and Setúbal Peninsula, with the corresponding per capita values of 173 and 292 kg.inhab$^{-1}$.year$^{-1}$, respectively. Also, for the same year a production of 3,607,449 ton are presented according to Eurostat (2015). Therefore, real and estimated numbers are mixed and it's difficult to obtained the exactly CDW amount. This fact is worse for the CDW from residential recuperation of small constructions, because these small works are not registered. According the Portuguese legislation (Decree-law n. 46/2008 and Decree-law n. 73/2011), all small enterprises with no more of 10 workers does not need to have his CDW database recorded at National Environmental Agency (APA – Agência Portuguesa do Ambiente).

In the last years some progress were made in the CDW with the implementation of national legislation (Decree-Law No. 46/2008), but unfortunately most of the CDW are going to landfill or dumped illegally. Considering the importance of CDW recycling for sustainable development, it is necessary to know the real situation and to promote new ways of reutilization and recycling even for small constructions.

The present study aims to quantify and characterise the CDW from residential recuperation of small constructions in specific areas from Portugal (Setubal Region) and then propose mitigating measures to suitable disposal.

**Methodology:**

To achieve the proposal goal in the present study, an extensive literature review was made on data published from European Commission, articles and thesis in order to collect data from the European situation and Portugal. The same was done with construction enterprises working in Portugal and waste management entities. Due to the high number the entities involved in the production, transportation and management of CDW it was necessary to select a specific region of Portugal and only after the scope can be expand. So, surveys targeted were sent to the entities that usually collect and treat the CDW, specially directed to the Setúbal district. Despite some global values of CDW and estimative values, there is no reference to small-scale works consisting essential on house remodelling. The survey requires general information, like the total amount of CDW by weight and/or volume. At the same time, it is asked the composition of the CDW by material type: concrete, wood, metal, glass, etc. Finally, the CDW destination was divided by reuse, recycling, landfilling or incineration.

In addition, there was a direct contact with City Halls of Setubal district (13 City Halls) and waste management entities (ME) to get information about CDW production in last years. An application form was send to all ME to be filled with several data including the final wastes disposal methods. With the information acquired from the surveys several determinations were made, like the per capita value.

**Results and discussion**

In the present study first is shown the information collected in terms of construction activity and CDW generation in Europe. In Europe the construction activity varies from country to country and, as a consequence, also the CDW production. According the Eurostat (2015) in EU 28

821,160,000 ton CDW were produced in 2012. The lowest value was presented by Latvia (7,509 ton) with a per capita value of 4 kg.inhab$^{-1}$.year$^{-1}$ and the highest value was from France (246,702,428 ton) with a per capita value of 3,771 kg.inhab$^{-1}$.year$^{-1}$. The differences between countries in generation of CDW per capita are higher than the differences in generation of municipal waste. The comparison CDW production and the per capita value between the countries in the Iberian Peninsula from 2004 to 2012 is presented in Figure 1.

Figure 1

In 2012, Portugal had a CDW production of 928,394 t with the corresponding per capita value of 88 kg.inhab$^{-1}$.year$^{-1}$. Spain has higher CDW values and presents a decreasing production since 2006. The Portuguese CDW values collected from Eurostat (2015) were compared with the INE (2010) values (Table 2), which presents the production sent to waste ME, from 2004 until 2009 by the economic activity according to Portuguese Classification of Economic Activities, Revision 3 (abbreviated to CAE-Rev.3) (CAE 43 to 43).

Table 2

The values in 2004 and 2008 are almost the same except for 2008, which difference can be explained by the adjustment of European Legislation in terms of type CDW regarded for the total CDW amount.

The CDW production evolution in Portugal since 2004 until 2011 (Table 2) presents a significant variation with the maximum value in 2006 and the lowest value in 2011. This fact can be related with the construction activity in the last years. Also the activity of construction has some specificities, such the geographical dispersion and the temporary nature of the works.

Figure 2 shows the evolution of construction activity in Portugal in last years.

Figure 2

As it can be observed in Figure 2 the construction activity in Portugal is decreasing from 2002, with a more or less linear decline since 2006.

Coelho & Brito (2010) indicate that the CDW production and the per capita values varies according to the Portugal region (Table 3).

Table 3

On the CDW data collected from ME (EGF group) (Figure 3) represent the waste generation from 60 % of Portuguese population, corresponding to 6.4 million inhabitant. In this case, a significantly variation occurs again from the different regions (Figure 4) (EGF, 2013).

Figure 3

Figure 4

As it can be observed in Figure 5 AMARSUL ME received the highest CDW amount. The collected data provided by AMARSUL from the inert fraction of CDW from 2009 until 2014 is presented in Figure 5 (AMARSUL 2009 to 2013).

Figure 5

As shown in Figure 5 the AMARSUL presents a decrease in the CDW collection from 2008 to 2012. Since 2012 the CDW values remains almost constant. However, this observation was made from AMARSUL values that it is not coincident with other publications from EGF Group.

Besides the significant quantities produced the CDW has other features that hinder its management, including its heterogeneous constitution with different fractions and different levels of hazardous substances (Table 4).

Table 4

In Portugal, despite the heterogeneous constitution, CDW average composition is mostly made up of concrete and ceramic materials, representing over 80% of CDW generated. The remaining materials, highlight the wood waste, metals and materials gypsum (Malia 2010).

In order to obtain the typical CDW composition in Portugal and due to the lack of real value from the surveys sent it was necessary to predict the values (Figure 6).

Figure 6

As mentioned in the methodology it was necessary to start with a specific region from Portugal. In order to characterise that region, data collection from each City Hall of Setubal district were made referring the population, buildings and houses (Table 5). On Table 6, it is possible to see the evolution and the distribution of remodelled buildings, which include construction works like expansion, alteration, rebuilding and demolition.

Table 5

Table 6

As previously mentioned, it is common to verify some illegal deposition of CDW, as evidenced by the Figures 7a and 7b taken in Setubal Region and in Portuguese islands, respectively.

Figure 7

However, municipal entities have ways to collect the CDW. Usually the CDW produced from small remodelling work performed in urban areas are collected in “big bags” up to 1 $m^3$ of capacity or others containers. Some municipalities accept higher volume until 5 $m^3$. In Table 7 a

resume of the CDW collection system by each City Halls from Setubal are presented. It is verified that the involved costs and the resources are not standardized even with the same ME.

Table 7

From several studies it's possible to verify that CDW are mainly sent to landfill (Melo 2011 and Mália 2010).

Nevertheless, the actual waste management hierarchy is based on the waste as a source of raw materials by reuse.

According to Mália (2010) several countries have developed policies in order to encourage prevention and reuse of CDW, with important results. The most effective measures to achieve high CDW recycling rates are the separation of waste at the origin and the high tax for CDW landfilling.

The CDW application in the production of recycled aggregates is one potential use by the incorporation in reinforced concrete as a replacement of natural aggregates (Rodrigues et al. 2013) or in cement mortars (Samiei et al. 2015). Nevertheless, to promote de CDW market it's particularly important to establishment quality criteria that induce the trust of potential customers in order to incorporate of recycled waste into new products.

The CDW is a flow waste with several options to be re-use, because the significantly inert fraction, but the scarce real amount production and the collection with other waste like municipal solid wastes difficult to promote an adequate process.

**Conclusion:**

The CDW survey in Portugal is a very complex task mainly due the poor existing information and the weak answers from all entities. This fact is more serious in small works because Portuguese legislation don't required the CDW record.

The Portuguese CDW production was about 930 thousand ton in 2011. This low value is a consequence of the construction and demolition activity decrease. The selected region (Setúbal) represent almost 1 % of the Portuguese Population, with a total of 206,603 buildings (468,168 houses). The CDW data from that region was mainly collected from the ME entities. The principal EM is AMARSUL which collect about 35,000 ton of CDW in 2014.

In this work, it is possible to see what information is disposable, in Portugal and other European countries and establish some correlation and homogenization.

**Acknowledgements:**

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Table 1. Codes to CDW from the European List of waste (Commission Decision 2000/532/EC)

| **Code** | **Description** |
|---|---|
| 17 01 | concrete, bricks, tiles and ceramics |
| 17 02 | wood, glass and plastic |
| 17 03 | bituminous mixtures, coal tar and tarred products |
| 17 04 | metals (including their alloys) |
| 17 05 | soil (including excavated soil from contaminated sites), stones and dredging spoil |
| 17 06 | insulation materials and asbestos-containing construction materials |
| 17 08 | gypsum-based construction material |
| 17 09 | other construction and demolition wastes |

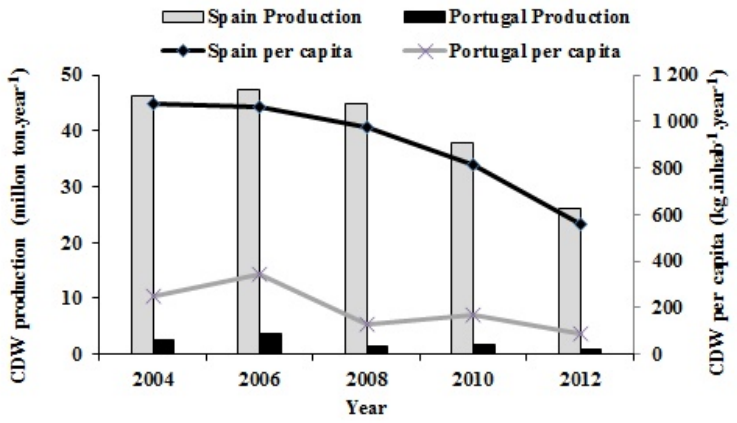


Figure 1. CDW production and per capita value in Portugal and Spain (Eurostat 2015)

Table 2. Portuguese CDW amounts from 2004 to 2011

| Year | CDW (ton) (INE 2010) | CDW (ton) (Eurostat 2015) |
|---|---|---|
| 2004 | 2,625,930 | 2,625,939 |
| 2005 | 5,212,520 | na |
| 2006 | 3,607,232 | 3,607,449 |
| 2007 | 5,674,248 | na |
| 2008 | 8,148,290 | 1,364,419 |
| 2009 | 3,152,098 | na |
| 2010 | na | 1,779,897 |
| 2011 | na | 928,394 |

na – Not availabe

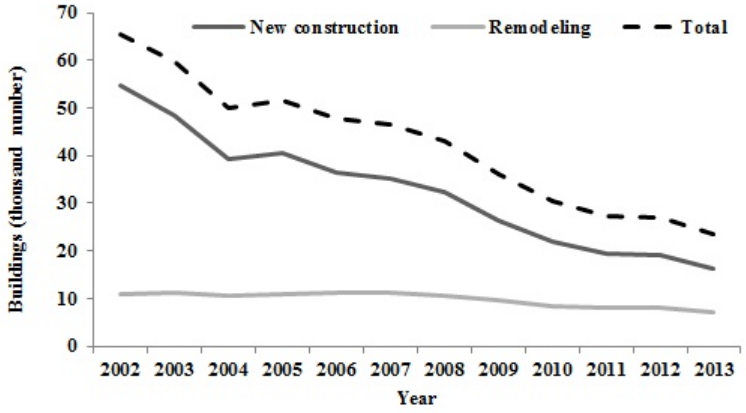


Figure 2. Construction activity in Portugal (INE, 2015)

Table 3. CDW from several region in Portugal (Coelho and Brito, 2010)

| **Region** | **CDW (2006) (ton)** | **Pop (2008) (inhab.)** | **Per capita (ton.inhab$^{-1}$.year$^{-1}$)** | **Per capita (kg.inhab$^{-1}$.d$^{-1}$))** |
|---|---|---|---|---|
| Norte | 1,432,265 | 3,745,439 | 0.382 | 1.048 |
| Centro | 1,327,148 | 2,383,284 | 0.557 | 1.526 |
| Lisboa | 581,659 | 2,819,433 | 0.206 | 0.565 |
| Alentejo | 477,910 | 757,069 | 0.631 | 1.729 |
| Algarve | 305,581 | 430,084 | 0.711 | 1.947 |
| Arquipélagos | 300,599 | 491,941 | 0.611 | 1.674 |
| Total (*Average) | 4,425,157 | 10,627,250 | 0.416* | 1.141* |

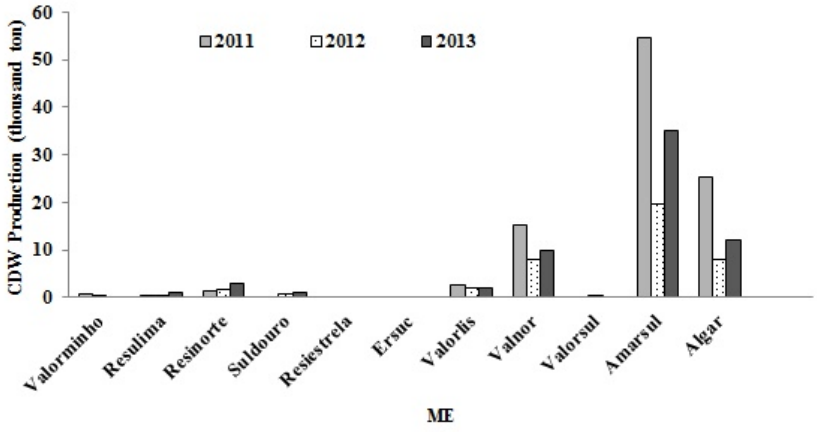


Figure 3. CDW production in ME from EGF (2011, 2012 and 2013)


Figure 4. Portugal map with the waste EM from EFG group (Adapted from EGF 2013)

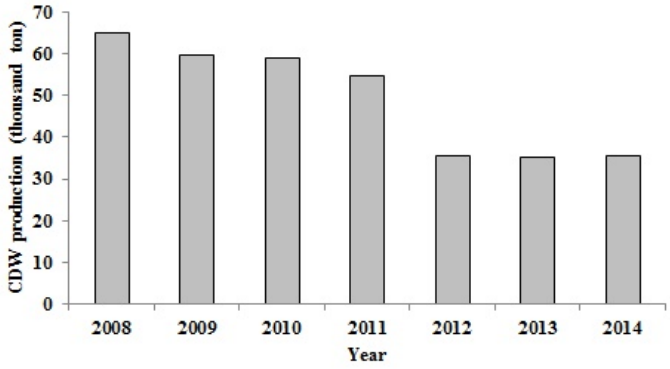


Figure 5. CDW from AMARSUL (AMARSUL 2009 to 2013)

Table 4. CDW from Norway (Statistics Norway, 2006 cited by Malia, 2010)

| Composition | Construction (%) | Rehabilitation (%) | Demolition (%) | Total (%) |
|---|---|---|---|---|
| Concrete and Ceramic masonry | 45.79 | 47.69 | 84.16 | 67.24 |
| Wood | 13.67 | 30.31 | 6.42 | 14.58 |
| Metal | 1.32 | 3.59 | 4.33 | 3.63 |
| Gypsum | 6.25 | 5.72 | 0.15 | 2.77 |
| Paper, Cardboard and Plastic | 4.5 | 0.89 | 0.27 | 1.14 |
| Glass | 0.47 | 0.41 | 0.12 | 0.26 |
| Insulation Materials | 1.87 | 0.51 | 0.07 | 0.49 |
| Asbestos | - | 0.7 | 0.32 | 0.38 |
| Other Hazardous Waste | 0.23 | 0.04 | 0.04 | 0.07 |
| Other Waste | 25.89 | 10.13 | 4.13 | 9.44 |

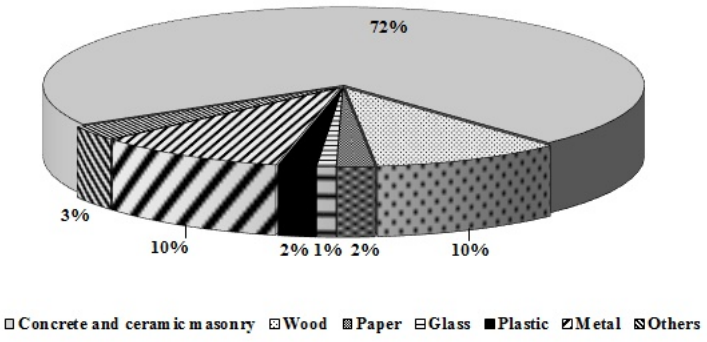


Figure 6. Typical CDW composition (adapted from Pereira (2002))

Table 5. Data for each City Hall

| | Area characterization | | | |
|---|---|---|---|---|
| **City Hall** | ***Population** | ***Buildings** | ***Houses** | ****Total area ($km^2$)** |
| Almada | 174,030 | 34,163 | 101,443 | 70.2 |
| Seixal | 158,269 | 30,124 | 79,486 | 95.7 |
| Barreiro | 78,764 | 11,008 | 41,739 | 32.0 |
| Moita | 66,029 | 12,398 | 34,659 | 55.3 |
| Montijo | 51,222 | 12,996 | 26,733 | 348.6 |
| Alcochete | 17,569 | 4,575 | 8,818 | 128.4 |
| Palmela | 62,831 | 21,631 | 33,141 | 465.1 |
| Setúbal | 121,185 | 24,242 | 62,749 | 230.3 |
| Sesimbra | 49,500 | 20,433 | 31,792 | 195.5 |
| Alcácer do Sal | 13,046 | 7,535 | 8,818 | 1499.9 |
| Grândola | 14,826 | 9,337 | 12,041 | 825.9 |
| Santiago do Cacém | 29,749 | 13,370 | 18,431 | 1059.7 |
| Sines | 14,238 | 4,791 | 8,318 | 203.3 |
| **Total** | **851,258** | **206,603** | **468,168** | **5209.9** |

* INE (2012) Censos 2011, ** PORDATA (2015)

Table 6. Buildings remodelling (number) data for each City Hall (INE, 2015)

| City Hall | Buildings Remodelling (number) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **2002** | **2003** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** | **2010** | **2011** | **2012** | **2013** |
| Alcochete | 1 | 4 | 1 | 7 | 5 | 5 | 3 | 2 | 4 | 4 | 2 | 7 |
| Almada | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 3 | 4 | 1 | 8 |
| Barreiro | 21 | 21 | 24 | 24 | 29 | 26 | 21 | 10 | 14 | 11 | 12 | 2 |
| Moita | 16 | 12 | 5 | 4 | 7 | 4 | 8 | 11 | 3 | 5 | 3 | 2 |
| Montijo | 6 | 8 | 2 | 4 | 11 | 8 | 13 | 13 | 10 | 9 | 11 | 10 |
| Palmela | 36 | 32 | 49 | 35 | 34 | 41 | 27 | 25 | 18 | 31 | 28 | 29 |
| Seixal | 16 | 15 | 9 | 5 | 9 | 13 | 5 | 15 | 7 | 5 | 5 | 2 |
| Sesimbra | 21 | 2 | 2 | 2 | 1 | 5 | 1 | 2 | 2 | 2 | 4 | 9 |
| Setúbal | 22 | 39 | 33 | 36 | 28 | 34 | 60 | 77 | 12 | 11 | 5 | 7 |
| Alcácer do Sal | 36 | 11 | 3 | 4 | 1 | 3 | 4 | 0 | 4 | 5 | 6 | 2 |
| Grândola | 17 | 22 | 29 | 20 | 16 | 13 | 17 | 12 | 14 | 13 | 15 | 19 |
| Santiago do Cacém | 70 | 66 | 65 | 65 | 78 | 107 | 138 | 142 | 115 | 130 | 79 | 43 |
| Sines | 6 | 11 | 15 | 23 | 25 | 29 | 28 | 20 | 10 | 22 | 16 | 17 |
| **Total** | 269 | 243 | 238 | 229 | 244 | 288 | 325 | 330 | 216 | 252 | 187 | 157 |


Figure 7. CDW dumped illegally in a) Setubal and b) Portuguese islands

Table 7. CDW collection system by each City Halls from Setubal

| City Hall | ME | Big bag cost (€/unit) [year] | Collection and transport | | | Additional information |
|---|---|---|---|---|---|---|
| | | | Responsibility | Local | Cost [year] | |
| Almada | Amarsul | --- | Producer | Ecocenter/Ecopark | Until 1m$^3$: free<br>>1m$^3$: 3.5€/ton [2015] | |
| Seixal | Amarsul | 25.36€ [2013] | Producer | Ecocenter/Ecopark | Until 1 ton/week: free<br>>1 ton: 2.73€/ton [2013] | The ecocenter reuse CDW to cover pathways at ecocenter |
| Barreiro | Amarsul | --- | --- | --- | --- | |
| Moita | Amarsul | --- | --- | --- | --- | |
| Montijo | Amarsul | --- | --- | --- | --- | |
| Alcochete | Amarsul | --- | Producer | Ecocenter/Ecopark | --- | Individual: cost - 6.60€ /big bag and free collection by municipal services [2015] |
| Palmela | Amagra (Ambilital) | 9.65€ [2009] | Until 1m$^3$: municipal services<br>>1m$^3$: producer | Ecocenter/Ecopark | --- | |
| Setúbal | Amagra (Ambilital) | --- | --- | --- | --- | Accomodation: big bags until 3m$^3$; >3m$^3$ container provision |
| Sesimbra | Amarsul | --- | --- | --- | --- | |
| Alcácer do Sal | Amagra (Ambilital) | --- | Until 1m$^3$: municipal services<br>>1m$^3$: producer | Ecocenter/Ecopark | --- | |
| Grândola | Amagra (Ambilital) | --- | --- | --- | --- | |
| Santiago do Cacém | Amagra (Ambilital) | --- | --- | --- | --- | |
| Sines | Amagra (Ambilital) | --- | --- | --- | --- | Deposition at Sines Ecocenter - 41.34€/ton |

Data collected from municipal entities sites