7

Separate Collection Systems for Urban Waste (UW)

Antonio Gallardo, Míriam Prades,
María D. Bovea and Francisco J. Colomer
Universitat Jaume I, Castellón,
Spain

1. Introduction

Separate collection of urban waste can be defined as a specific collection system that allows recoverable materials in waste to be separated. The human factor is very important in this new collection model, as the citizen now plays an active rather than a passive role as a processor of materials at source.

Various solutions for separate collection have emerged in order to fulfil all the objectives stipulated by legislation and local authorities in various countries for the recovery of municipal waste. Germany uses the Dual System, in which packaging waste is collected separately by a network belonging to companies selling consumer products. Separation of the organic fraction is mandatory in the Netherlands. In France and Spain, the governments are the responsible for designing mechanisms to implement the separate collection of packaging waste and achievement of the goals stipulated by European legislation. In the USA and Canada in the early 1990s, many cities with residential areas containing single-family homes began pilot schemes for separate collection, with waste separated at source into two, three and four fractions.

The large number of factors involved in establishing a separate collection system (economic, social, environmental, legal, etc.) means that there is no single solution or alternative. This has given rise to studies of citizens' behaviour with regard to the various collection systems: the level of participation, quality of the waste collected, financial incentives, etc. (White *et al.*, 1995; Wang *et al.*, 1997, Gallardo, 2000, Martin *et al.*, 2006, Shaw *et al.*, 2006, Dahlén *et al.* 2007). Other authors have analysed the various demographic, logistic and economic factors influencing citizens' participation, and assessed the quantities collected, generation and composition data for certain indicators based on these factors (Daskalopoulos *et al.* 1998, Emery *et al.*, 2003, González-Torre & Adenso-Díaz, 2005).

Separate collection of organic waste has been implemented in countries in northern Europe for several years, and is now relatively well established there. It is not yet widespread in Spain or others countries in southern Europe, but there are experiences in many autonomous regions at local or regional level which have had varying degrees of implementation and success. The Framework Directive on Waste (Directive 2008/98/EC) introduced the concept of biowaste and the need to recover this type of waste. The organic fraction of urban waste is considered biowaste, and it accounts for 36% (UE, 2011) of urban waste. As such, its separate collection is expected to be enhanced in all European Union countries, in order to use it and minimize its deposit into landfill.

2. Legislation

When planning the management of municipal solid waste in a particular area or region, the various actions and initiatives must be arranged hierarchically in accordance with the needs imposed by the environment. The hierarchy thus established will essentially depend on the policies of each region or state at a particular moment in time. Under Directive 2008/98/EC, European Union member states must observe the following hierarchy in waste management; it can be also used as a list of priorities for legislation and policies concerning waste prevention and management:

- Prevention
- Preparing for re-use
- Recycling
- Other recovery, e.g. energy recovery
- Disposal

However, the Directive also states that when this waste hierarchy is applied, the member states shall take steps to foster the options that provide the best overall environmental outcomes. This could mean that certain waste streams have to be removed from the hierarchy when a life cycle approach to the global impacts of waste generation and management calls for it.

As far as the evolution of the legislation on packaging and packaging waste is concerned, the recovery targets in the first Directive passed on this subject (Directive 94/62/EC) were:

- Recovery of 50-65%, by weight, of packaging waste before 2001.
- Recycling of 25-45%, by weight, of packaging waste, with a minimum of 15% for each material, before 2001.

The following Directive (Directive 2004/12/EC) is far stricter and raised the recovery targets to be achieved in 2008, which now stand at:

- Recovery: minimum 60% by weight (includes incineration with energy recovery)
- Recycling: between 55-80%, by weight, of the total amount of packaging waste. With the following minimum values:
- 60% by weight of glass
- 60% by weight of paper/cardboard
- 50% by weight of metal
- 22.5% by weight of recyclable plastic
- 15% by weight of wood

The progressive changes introduced into the legislation have meant that town councils have also had to evolve in terms of the separate collection methods and programmes they use in order to adapt to the new limits established by the legislation.

3. Urban waste separate collection systems

Separate collection is part of the comprehensive urban waste management system, which covers everything from collection to disposal (Tchobanoglous *et al*., 1994), but which can be studied as a separate subsystem consisting of the pre-collection and collection stages (Figure 1). When studied separately, it can be considered an independent system, in which the input consists of a stream of urban waste and the output is several streams of selected materials, which go to the next management stage where it is subjected to different recovery methods. Separate collection is influenced by a number of environmental factors that influence the choice of the alternatives in the two elements of the system.

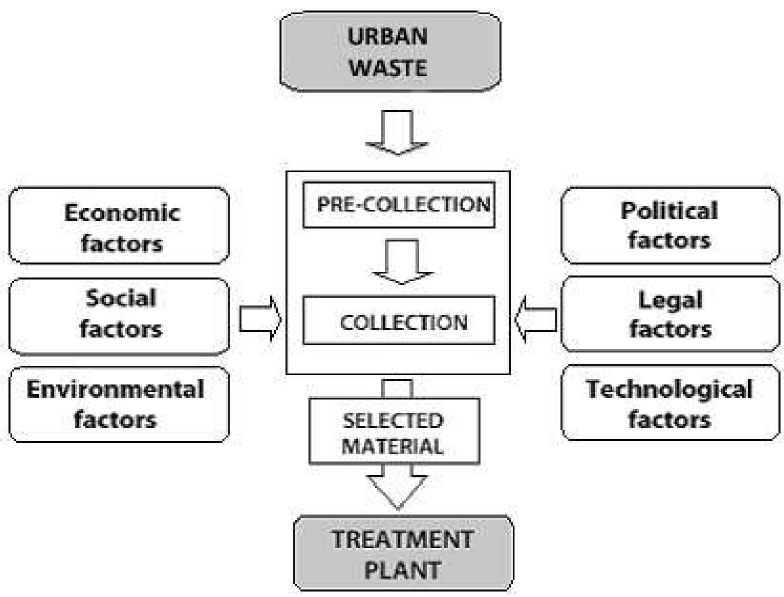


Fig. 1. Separate collection diagram.

Pre-collection includes handling, processing and storage of urban waste by citizens before it is deposited at the collection points, where there are different types of containers (Figure 2). After it has been deposited and stored at these points, the waste is collected and transported to the next facility in the urban waste management system. Most recovery methods, such as recycling or incineration, require separation into different fractions at source in order to achieve the minimum quality levels required in these processes. To that end, there is a wide range of fractioning at source, which can range from level zero, i.e. unfractioned or "all in one" collection, to a high level of specific separation of materials (Table 1).

Fig. 2. Urban waste collection containers in Spain.

Without fractioning	Total urban waste 
Two fractions: organic and mixed waste	Mixed Organic 
Three fractions: organic, lightweight and mixed waste	Mixed Organic Lightweight 
Specific separation: mixed and specific waste	Mixed Specific 

Table 1. Types of fractioning at source.

Once the waste has been separated, the question is what to do with it until it is collected. It is usually stored at home or at collection points located on the street (Figure 2). There are several levels of storage, depending on the distance travelled by the citizen to the deposit point:

- *The door to door system*. The bins or containers are located at each door, courtyard or other area accessible from the home or building. The distance that the citizen has to travel to deposit the waste is minimal.
- *The kerbside system*. The deposit points are no longer located at the door, but every 50-60 m on kerbsides. Citizens do not have to travel very far and acceptance is good. This system is applied in cities with high population densities.
- *The drop-off points system*. Collection points are located at greater distances in order to reduce management costs. The areas may have a range of between 100 and 300 m. The system relies on citizens' willingness to travel longer distances on foot. Figure 3 shows two drop-off points for dropping off paper-cardboard, glass and lightweight packaging (plastic, metal and liquid packaging board) separately.
- *Deposit at establishment level*. Some establishments (shops, public institutions, etc.) collaborate in the separate collection of some types of waste, particularly hazardous waste such as batteries, fluorescent lamps and drugs.
- *Deposit at facility level*. Deposit points are located in facilities away from the residential area. These facilities are called "Clean points", "Ecoparks" and "Recovery and Recycling Centres" (Household Waste Recycling Centres in the United Kingdom). They are able to selectively collect all types of waste, especially those that are not collected at other levels. An ecopark in Spain is shown in Figure 4.

Combining the different types of separation at source with storage levels can create a wide range of pre-collection systems. At one extreme is "all in one" pre-collection and the "door to door" level, which is the most convenient alternative from the citizen's standpoint. The managing agent is responsible for separation and recovery, which is more expensive and very inefficient in terms of recovery of materials. At the other extreme is collection with specific fractioning (paper, glass, packaging, batteries, etc.) at establishment and facility level. In this case, citizens have greater responsibility for separation, and materials with added value for the manager are obtained.

Fig. 3. Collection at drop-off points in Switzerland (left) and Spain (right).

Fig. 4. Ecopark or clean point in Spain.

3.1 Efficiency indicators

In order to determine the level of efficiency of a separate collection system, it is necessary to define some indicators. This efficiency has been defined in terms of the level of recovery of clean materials at source, deposited in the container, which is in turn expressed in terms of a series of indicators (Gallardo *et al*. 2010):

- *Fractioning Rate* (FR_i): the ratio between the amount by weight of the raw material separated and the total amount of urban waste. This rate is used to measure the various collection streams.

$$FR_i = \frac{\text{Gross amount of waste collected in container for } i}{\text{Total amount of urban waste}} \cdot 100(\%)$$

Where i is p, g, lp, o or uw depending on whether the FR is for paper, glass, packaging, organic waste or household waste, respectively. Raw material refers to material contaminated to a greater or lesser extent by other unwanted materials (also called improper materials).

- *Separation Rate* (SR_i): the ratio between the amount by weight of raw material separated and the total amount of material in the urban waste.

$$SR_i = \frac{Gross\ amount\ of\ waste\ collected\ in\ container\ for\ i}{Total\ amount\ of\ i\ waste\ generated} \cdot 100(\%)$$

For example, to find out the *SR* of the paper-cardboard in the paper container, we divide the amount of separated paper by the total paper in the waste.

- *Quality in Container Rate* (QCR_i): the ratio between the amount of net recyclable materials deposited in a container and the gross amount deposited in them.

$$QCR_i = \frac{Amount\ of\ waste\ collected\ correctly\ in\ container\ for\ i}{Gross\ amount\ of\ waste\ collected\ in\ container\ for\ i} \cdot 100(\%)$$

A good system would be one with a high *SR* with high quality materials, i.e. a low proportion of improper materials. These indicators are a necessary tool for evaluating the efficiency of the infrastructure of the separate collection system implemented. They provide direct information on the total quantities and products obtained in each type, in comparison with the potential amount of recyclable materials present in urban wastes. They are also useful for a diagnosis of the situation of the separate collection programme implemented and for finding out whether the poor quality of the materials collected separately is due to low participation, poor performance in collection or a lack of public information, for example.

3.1.1 Factors affecting the separation rate

The *SR* is directly related to the public's participation in separate collection programmes. This participation depends on several factors, which Wang *et al.* (1997), grouped into two categories: factors related to the citizen's attitude and factors associated with the characteristics of the collection programme. Few studies have been carried out in this area (Noehammer *et al.*, 1997), although some researchers have found interesting results that relate the *SR* to various factors:

- *The economic factor*. Noehammer *et al.* (1997), in a study on the impact of free separate collection bins on the degree of participation, concluded that providing bins in voluntary programmes has a positive effect. However, they were unable to confirm anything for compulsory programmes. They also showed that if the fee paid directly for the collection of municipal waste falls, the level of participation increases. Gilnreiner (1994) presents the results of a survey conducted in Vienna in which "reward systems" are clearly preferred by consumers over "punitive systems" such as ecotaxes and packaging taxes. Another way to increase the degree of participation is through the introduction of tax benefits (Bolaane, 2006) or by lowering the fees paid for collection (Harder & Woodard, 2007)
- *Size of housing*. Participation in high-rise housing, which is usually small in area, is lower than in single-family homes, which are generally larger. On the other hand, it is

easier to monitor who is participating in separation in the latter, while in a block of flats this is more difficult. Following this argument, in the Netherlands it has shown that occupants of tall buildings are more reluctant to participate (White *et al*., 1995).

- *Frequency of collection*. If collection is infrequent, citizens' motivation declines, while if frequency is appropriate and in line with the rate containers are filled, participation increases (White *et al*., 1995).
- *Number of fractions*. The level of participation falls as the number of fractions into which urban household waste is divided increases. Noehammer *et al*. (1997) studied the influence of the number of separations on the degree of participation in 104 separate collection programmes and found that for a separation into two fractions, participation is between 75-95%, while for more than four fractions the range was 49 -92%. Another conclusion they obtained was that in mandatory programmes, there was no clear correlation between the level of participation and the number of separations. However, when the programme was voluntary, the level of participation declined as the number of fractions increased.
- *Distance to the deposit point.* Participation falls as the distance to the deposit point increases. In Spain, the *SR* for glass in kerbside collection was 40% (distance to container 50 m), while at drop-off points, with a range of between 100-160 m, the average is 22% (Gallardo *et al*., 1999).
- *Compulsory separate collection.* Compulsory separate collection programmes have a higher level of participation than voluntary programmes, providing that they are accompanied by certain incentives. Noehammer *et al*. (1997) found in their study that in compulsory programmes the level of participation had a range of 49-100%, while in voluntary collection it ranged between 11% and 92%, and concluded, as did the other authors that they cite, that compulsory programmes are more successful provided that they are accompanied by a high level of information, financial incentives, an adequate collection frequency, free containers, etc.
- *Socioeconomic level.* Gandy (1994) and Belton *et al*. (1994), in two studies on the relationship between socioeconomic level and the degree of participation in the drop-off points, found that there was participation clearly increased among people with a higher socioeconomic level. However, Lober (1996) in a study of reduction at source and recycling, found that in the various recycling programmes he studied, the socioeconomic factor was not significantly correlated with the degree of participation.
- *Education and promotion*. The level of information received by the public influences the degree of participation and quality of the separated materials. Gallardo (2000) showed that in Spain the *SR* of glass and paper-cardboard at the drop-off point level was higher in cities where citizens were better informed, for the same range.
- *Sociodemographic characteristics.* These characteristics have become a basic tool for many researchers when evaluating the profiles of a participatory individual compared to another person who does not participate in collection programmes. This classification also makes it possible to take education and awareness-raising action among groups with low participation (Rojas *et al*. 2008). Nationality, socioeconomic status, age and gender, among other factors, correlate strongly with separation behaviour (Rojas *et al*., 2008). In Preston (England), Perry & Williams (2006) conducted research on participation in separate collection programmes, including the factor of nationality, because ethnic minorities now constitute a significant proportion of the town's

population. The study found that nationality that anticipated most in the recycling programme was the Indian-British minority (95.2%), followed by the British (78%) and the category of "other ethnic groups" (56.3%). The authors note that the reasons for the differences shown are unclear and require further investigation.

3.1.2 Factors affecting the quality in container rate

High levels of contamination can lead to considerable variations in the real quantities of material collected separately, its quality and its market price. To improve the *QCR* in pre-collection, the design of educational and social awareness campaigns and initiatives may be helpful. The input of contaminating materials may be due to different causes, of which the most common are:

- Deposit of waste in the wrong container.
- Deposit of the correct material but in the wrong format, such as depositing plastic toys in a container for plastic packaging.
- Deposit of dirty material, such as glass packaging with metal caps.

As with the *SR*, the *QCR* is also affected by numerous factors. The most important of these are:

- *The number of products separated together*. The fewer the different materials deposited in the same container, the higher the *QCR* achieved. The highest levels are reached in specific or single-material containers. Paper-cardboard containers in Spanish cities can achieve a QCR_p of 99.5% (Gallardo *et al*., 2010). Kelleher (1996), in a study on the *QCR* in door to door collection with four fractions (organic, glass, paper-cardboard and packaging) found that the packaging fraction (plastic, metal and cardboard packaging) had 35% of improper materials while the paper fraction only had 2%.
- *Degree of complexity in separation.* Citizens are more sensitive to generic concepts than specific details, and as such the more specifications asked for in the separation, the lower the *QCR* obtained. This was confirmed in the Mancomunidad (Commonwealth of Municipalities) of Pamplona (Spain) (MCP 1997), which specified what type of plastic had to be put in the packaging container, and only 34% of the plastic was in fact the type specified.
- *The pre-collection characteristics*. When materials are presented in open bins, contamination levels are lower (5-8%) as the fact that the containers are open means that their contents can be inspected. When closed containers or bags are used, contamination levels rise to 27-36% (White *et al*., 1995). Ayerbe (2000) presented a study conducted in a Spanish city which compared the quality of packaging collected in 1100 liters containers with an open lid and a closed lid (a system in which the container has an opening the size of a rubbish bag) and showed that in the former, the amount of improper materials (QCR_{lp}= 50%) was much higher than in the latter (QCR_{lp}= 74%)
- *Degree of public information*. Information campaigns have a major effect on the *QCR*. Various experiences have shown that if clear guidance is given to citizens on how to make the selection, they separate the different categories of waste perfectly. In the case of the Commonwealth of Pamplona (MCP, 1997), when there is separate collection in two fractions (recyclable materials and mixed waste), in 1995 the rural area had a *QCR* in recyclable material containers of 58%. A year later, after an information campaign

designed specifically for them, this had increased to 64%. According to Kimrey (1996), the information-education programme must be targeted at the entire family as if not, it is possible that not all members will collaborate in separate collection.

4. Separate collection systems in Europe

Since there are new European standards that must be complied with in terms of recycling targets, local authorities in countries belonging to the European Union have hastened to develop new collection models. As a result, a wide variety of separate collection systems can be found throughout Europe. This has given rise to their study and comparison in the different countries where they have been implemented. For example, in Sweden, Dahlén *et al*. (2007) conducted a study that compared 3 systems. The first consists of kerbside collection of recyclables and organic waste, including a specific case in which fees are paid for the collection of mixed waste. The second involves kerbside collection of recyclables, and the third the collection of recyclables at drop-off points. After the study, it was concluded that in municipalities with a kerbside collection system for recyclables, the mixed waste container has a higher *QCR* due to the proximity of the containers to the public. The introduction of the fee payment system for the collection of mixed waste led to this waste from many homes being burnt or dumped in the wrong place. In fact, in the municipality where this system was in place, the level of improper materials was 12% compared to 4% in one of the municipalities where this model was not implemented.

Mattsson *et al*. (2003) produced a study that compared separate collection systems in both single family and multifamily property close areas in Sweden and England. They used 6 Swedish examples and one recently introduced case in the United Kingdom as examples. The cases analysed showed that although the technical details were almost identical, they differed in terms of how they had been developed. The aspects taken into account for their different developments were: cooperation between the municipality and producers, the efficiency in collection using appropriate vehicles, the quality of the materials collected, Agenda 21 and environmental awareness.

In the United Kingdom, Woodard *et al*. (2001) analysed waste collection in a district before and after the introduction of a new plan. Under the old system, mixed waste was collected in black bins and recyclables (paper, cardboard and metal) in a box, every week in both cases. The new plan (CROWN: Composting and Recycling our Waste Now) added a green container for the collection of biowaste every two weeks. The frequency of mixed waste collection declined and became fortnightly, like biowaste. The container volumes and satisfaction of citizens was noted in a sample of households in a residential area. The result was a 55% reduction in waste sent to landfill sites, an increase from 5.5 to 17.7 liters in the average amount of deposited recyclables per household per week, and a rise in participation from 40% to 78%. Wilson and Williams (2007) subsequently analysed the implementation of a new collection system in a northern town in the United Kingdom. Two samples with different collection frequencies were used to see which system worked better: in one the mixed waste and recyclables were collected in alternate weeks, and in the other the mixed waste was collected weekly and the recyclables fortnightly. The proportion of containers brought to the street for collection compared to the total number of containers available was analysed in each sample, as was the level of material recovery in each sample. Both calculations produced better results in the first sample.

In Cappanori (Italy) four fractions are collected door to door: organic, multi-material, paper-cardboard and mixed waste. All the fractions are collected by the same truck on different days, so that each time one fraction is collected. In this way, you save considerably on transport (Connett, 2011).

In Portugal, Gomes *et al*. (2008) produced an economic comparison of three alternatives in terms of the collection of biowaste. The alternatives were: collection of biowaste without separation, separation of biowaste in the whole municipality and the separation of biowaste in the main urban centres and home composting in the rest. The costs of collection and transportation in the three stages were quantified and it was found that compared to the first, which was the one used in the study area, in the second the costs would not necessarily be higher, and costs could even be lower with the third.

In Spain, Ayerbe and Pérez (2005) analysed three lightweight packaging collection systems. The first consisted of collection from drop-off points. The second consisted of kerbside collection, next to the mixed waste container, using open top containers. The third was the same as the second but used closed lid containers (The closed lid has a hole with the size of a rubbish bag). A comparative analysis was performed of *QCR*, the yield of the packaging selection plant (the ratio between packaging material entering and leaving the plant). As for the *QCR*, the worst system was the open top, which obtained a proportion of improper materials of over 50%. In terms of performance on the ground, the best system was the first (73.4%) followed closely by the closed lid system (68.7%). Berbel *et al*. (2001) carried out a similar study in Cordoba. They compared two types of collection of lightweight packaging: with a container exclusively for this type of waste and a container for inert waste (packaging and other inert materials). The results showed that more mixed waste was collected from containers with the second system. Gallardo *et al*. (2010) conducted a study to determine the separate collection systems in place in Spanish towns with over 50,000 inhabitants, and their efficiency. They found that there are four different systems (Figure 5) and the most common is separation into four fractions: paper-cardboard, glass, lightweight packaging (plastic, metal and liquid packaging board) and mixed waste: mixed waste is collected at kerbside, while the paper-cardboard, glass and packaging are collected at drop-off points. They also found the *FR* for the four models. The main difference was that in the *FR* for packaging, this

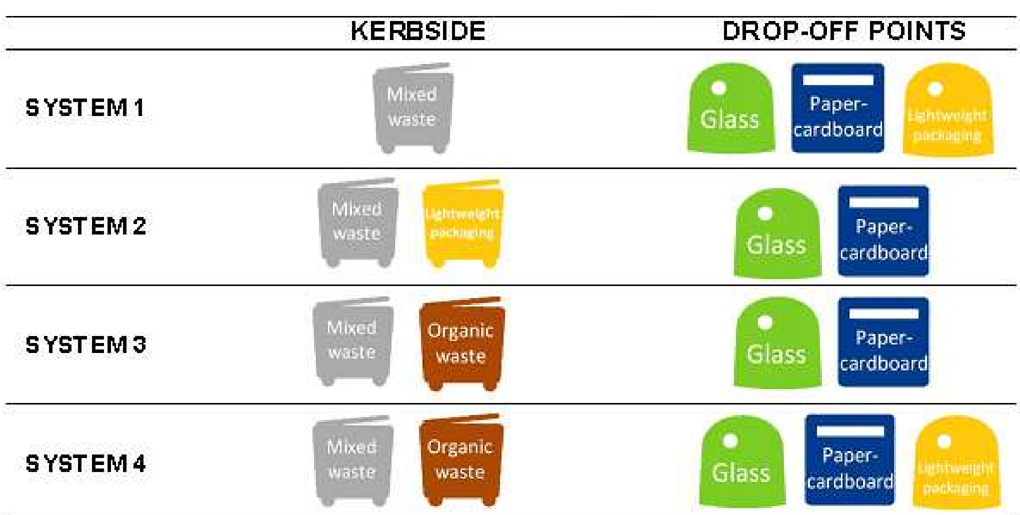


Fig. 5. Pre-collection models implemented in Spanish cities.

index is greater when lightweight packaging is deposited in kerbside bins (System 2), due to the fact that citizens have to travel a shorter distance to dump it. Furthermore, the materials left in System 2 contain a higher percentage of unwanted materials than when they are collected at drop-off points (System 1 and System 4), i.e. the QCR_{lp} is lower. This is due to the proximity to the mixed waste bin and to the fact that when it is filled to overflowing, citizens leave their waste in the lightweight packaging bin. In addition, in the collection of paper/cardboard, glass and lightweight packaging at drop-off points (System 1 and System 4), the *SR* of these fractions varied depending on the distance that people had to travel to deposit their waste; in specific terms, the greater the distance the lower the *SR*.

5. Separate collection systems for biowaste

An average of 520 kg of urban waste was generated *per capita* in the European Union in 2005 (Blumenthal, 2011) and this figure is expected to rise to 562 kg by 2020 (EU, 2011). If we consider this prediction to be correct, 290 million tons will be generated in 2020, of which 36% will be organic waste, and as such the amount would rise to 104.4 million tons. This is a very significant amount, and as such one would expect that the technology and the number of facilities for the use of this material would be greatly enhanced.

The organic fraction of urban waste consists of biodegradable materials (food scraps, spoiled food, gardening waste, etc.). European Union legislation, in the Framework Directive on Waste (Directive 2008/98/EC) defines "biowaste" as "biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises and comparable waste from food processing plants", meaning that the organic fraction can be classified as biowaste, like wood, sewage sludge, and agricultural and forestry waste. This is very important from a legal standpoint, since this Directive requires EU member countries to implement separate collection and recovery, thereby reducing greenhouse gas emissions, the recovery of biowaste as biogas and compost, and a reduction in the amount of waste dumped at landfill sites.

The main objective of the separate collection of the organic fraction of urban waste is to convert it into high quality compost. This material can be used as fertilizer for agriculture, gardening or landscape restoration work. The critical factor is the percentage of improper materials accompanying the organic fraction of urban waste. It is therefore essential that this operation is carried out under the best possible conditions.

The greatest difficulty in establishing a separate collection system is designing the pre-collection, to make it as convenient as possible for citizens and not unduly expensive for the Council. Two aspects depend on public participation: the amount of waste collected and its quality. The former justifies the system's existence and the latter prevents composting centres from receiving waste that is more similar to the mixed waste fraction than the organic fraction, as occurs in some cases. Another important external factor that can affect the system is the existence of a potential market which guarantees the destination of the compost in the territory of the composting plant. If this market does not exist, alternatives such as biomethanation or incineration after drying can be considered. In order to minimize the energy costs of drying, biological drying systems (biodrying), solar drying or a combination of both can be used (Adani *et al.*, 2002, Velis *et al.*, 2009, Zhang *et al.*, 2009).

The systems that can be applied to the collection of the organic fraction of urban waste are the same as those mentioned above. As described above, special attention must be paid to the pre-collection, which consists of separation in an organic waste bin, preferably in compostable bags, such as those made of corn starch. The bags are then deposited in special containers for transport to composting plants. In order to minimize the amount of improper materials appearing in the containers, initial campaigns and information maintenance initiatives are carried out, and biodegradable bags are often given away. It is also quite useful to conduct a pilot test in one part of the city, in order to gain experience and roll out the service to the rest of the city.

In order to increase the amount collected and reach more generation points, the collection of material can also be arranged according to its origin (Marrero, 2010):

- Household (fruit and vegetable peelings, food scraps, fish scraps, meat bones and scraps, spoiled food, grass cuttings, small prunings, etc.).
- Restaurants, bars, schools and public buildings.
- Waste from markets, shops and services.
- Waste from parks, gardens and cemeteries.

After a separate collection system for the organic fraction of urban waste that meets the needs of the population concerned has been established, its main advantages are:

- It generates higher quality compost than the mixed waste fraction, which needs prior treatment.
- Reduced costs of subsequent treatment of the compost (compost refining).
- It minimizes the problem of landfill leachate.
- It complies with regulations currently in force.
- Biocompartmentalized containers are available, making savings during collection possible.

6. Case study: Efficiency of separate collection of the organic fraction in Spain

In order to meet European targets on waste (Directive 2004/12/EC) and comply with Spanish law, which requires councils in towns with over 5,000 people to implement separate collection systems, Spanish councils have had to design new collection models to adapt to these laws. For this reason, there is a wide variety of collection systems in Spain.

We present the results of a research paper which analyses separate collection systems for organic waste in Spanish towns with between 5,000 and 50,000 inhabitants. The systems and their efficiency are studied using the indicators *Fractioning Rate and Quality in Container Rate* and *Separation Rate*.

In the year taken into account in this study (2008), the population of Spain rose from 46,765,807 inhabitants in 2008 (INE, 2008a). In addition, according to data released by the Spanish National Institute of Statistics, 24,240,470 tonnes of municipal solid waste were collected in the year 2008, and the *per capita* collection rate was 611.82 kg (INE, 2008b).

The number of municipalities with between 5,000 and 50,000 inhabitants in 2008 was 1,145 (INE, 2008a). Studying this entire population would be a difficult task and would entail considerable time and effort. To that end, a representative sample of that population (279 towns) was defined according to a number of statistical variables. Each one was sent a survey by mail, requesting the following information:

- General information about the municipality: number of inhabitants, area and collection system in place.
- For each of the waste fractions collected separately: tonnes collected annually; composition; the year separate collection was implemented; the number of containers and frequency of collection.

After the entire information gathering process, data was available for 115 towns (41% of the towns in the sample), in 14 of the 17 Spanish regions.

Of all the towns for which information was available, 29.5% collect the organic fraction of urban waste, the majority are in the region of Catalonia, as the legislation there requires this type of collection. Such a low percentage is due to the fact that collection of the organic fraction of urban waste is still voluntary, and as such the majority of the towns have not yet implemented it. According to the study, there are 6 different collection systems, with the following characteristics:

- SYSTEM A: separation into 4 fractions (mixed waste, organic waste, paper-cardboard and glass). Mixed waste and biowaste is collected at kerbside, while paper-cardboard and glass are collected at drop-off points.
- SYSTEM B: separation into 5 fractions (mixed waste, organic waste, paper-cardboard, glass and lightweight packaging). Mixed waste and biowaste is collected at kerbside, while paper-cardboard, glass and lightweight packaging are collected at drop-off points.
- SYSTEM C: separation into 5 fractions (mixed waste, organic waste, paper-cardboard, glass and lightweight packaging). Mixed waste and biowaste is collected at kerbside, while paper-cardboard, glass and lightweight packaging are collected at drop-off points. The collection of biowaste is partially implemented and collected door to door. This is a variation on System 4.
- SYSTEM D: separation in 4 fractions (mixed waste, organic material, glass and multi-product[1]). Mixed waste and biowaste are collected at kerbside, while multi-product and glass are collected at drop-off points.
- SYSTEM E: separation in 4 fractions (mixed waste, organic material, glass and multi-product). Mixed waste, biowaste and multi-product are collected door to door, while glass is collected at drop-off points. This is a variation on System D.
- SYSTEM F: separation into 5 fractions (mixed waste, organic waste, paper-cardboard, glass and lightweight packaging). All fractions are collected at the kerbside.

The diagram of the 6 collection systems can be seen in Figure 6. Table 2 shows the towns that have implemented each of the systems above.

Table 2 shows how system B is used in most of the municipalities studied. There is a new fraction, multiproduct, in systems E and F, in order to optimize collection. This fraction is not very widespread, and is not found in large Spanish towns (Gallardo et al., 2010). Figures 7-12 shows the different FR_o obtained by each system and Table 3 shows the QCR_o and SR_o for organic waste.

[1] Multi-product: light packaging and paper-cardboard

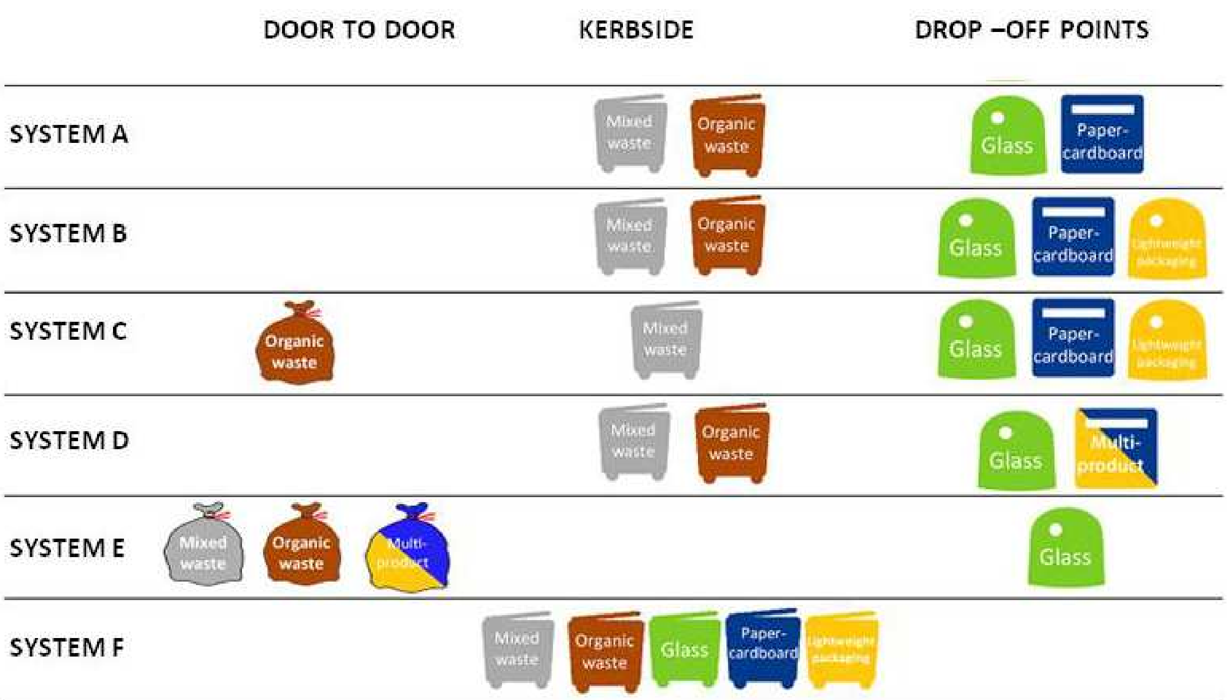


Fig. 6. Diagram of separate collection systems.

SYSTEM	No. cities
A	7
B	16
C	2
D	2
E	2
F	1

Table 2. Towns with between 5,000 and 50,000 inhabitants with each system.

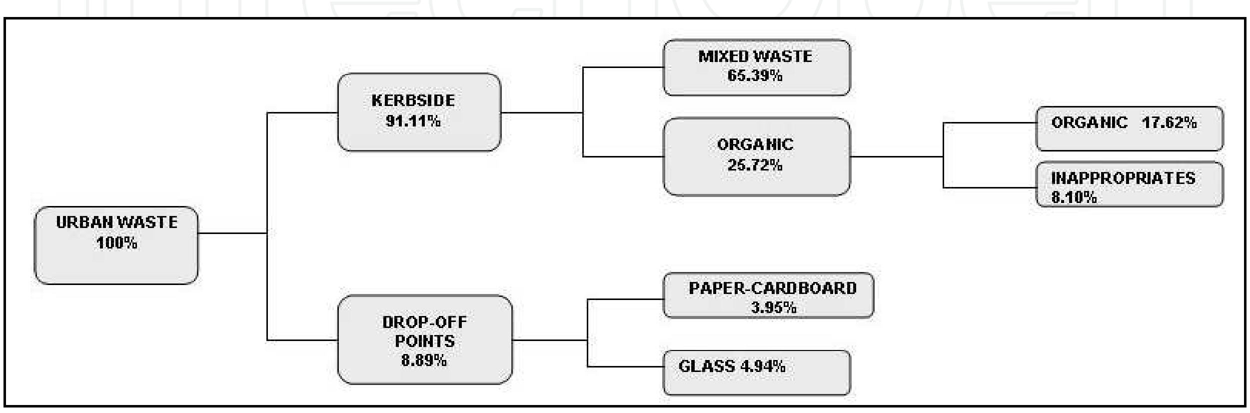


Fig. 7. System A Fractioning Rates.

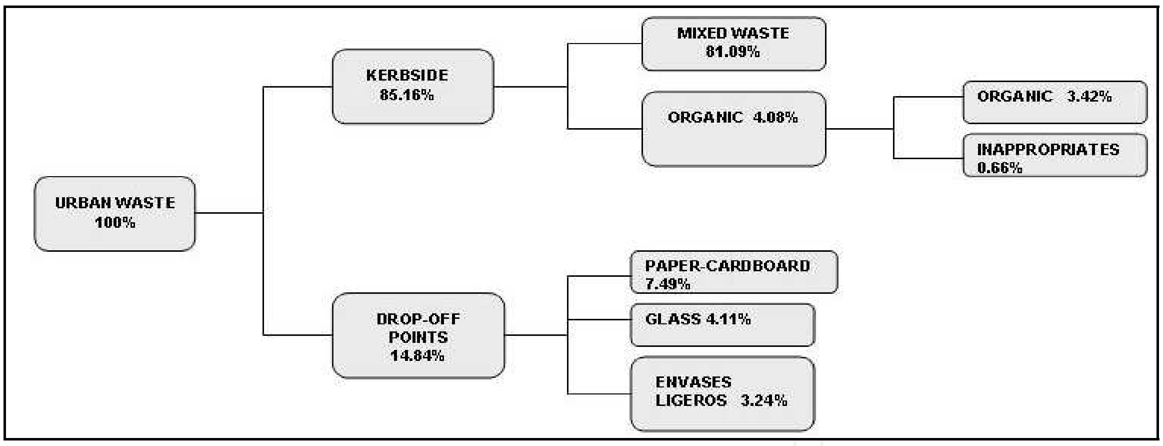


Fig. 8. System B Fractioning Rate

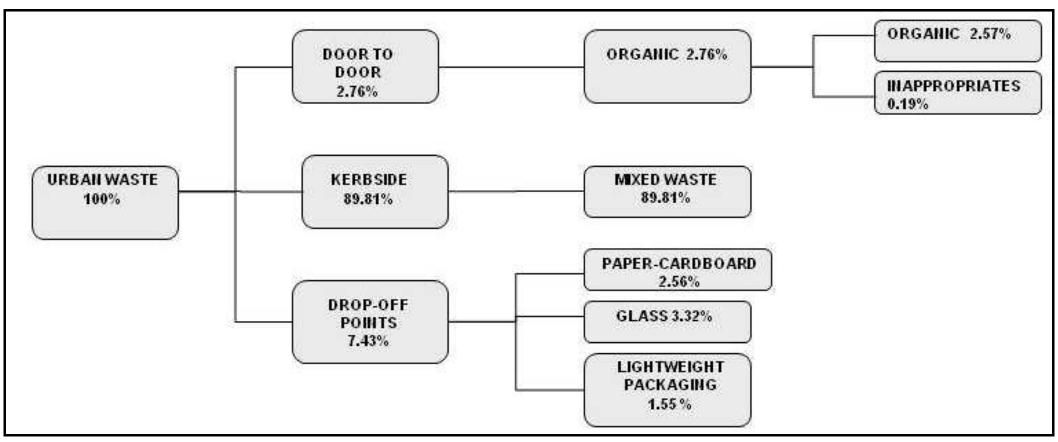


Fig. 9. System C Fractioning Rate

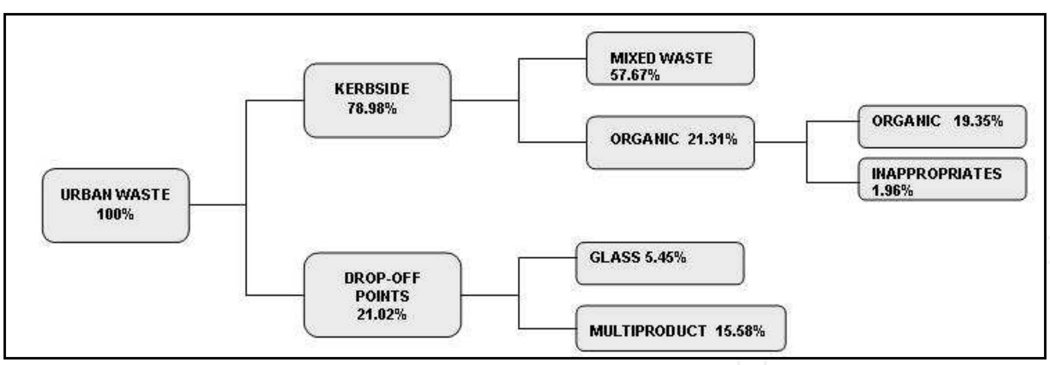


Fig. 10. System D Fractioning Rate

Using the FR_o and QCR_o calculated, it can be seen which system works best from the point of view of collection of the organic fraction of urban waste. The best FR_o results are obtained in system E, which also has the best QCR_o. The collection is door to door, which is very convenient for citizens, who do not have to travel any distance to deposit their waste. This system is suitable for towns in which the containers can be located inside buildings or homes. The worst FR_o and QCR_o results are for systems C and A respectively. The low FR_o is because the public participation is very low, as people prefer to deposit their waste in kerbside containers. Despite the low FR_o in system C, its QCR_o is high, which means that the few people

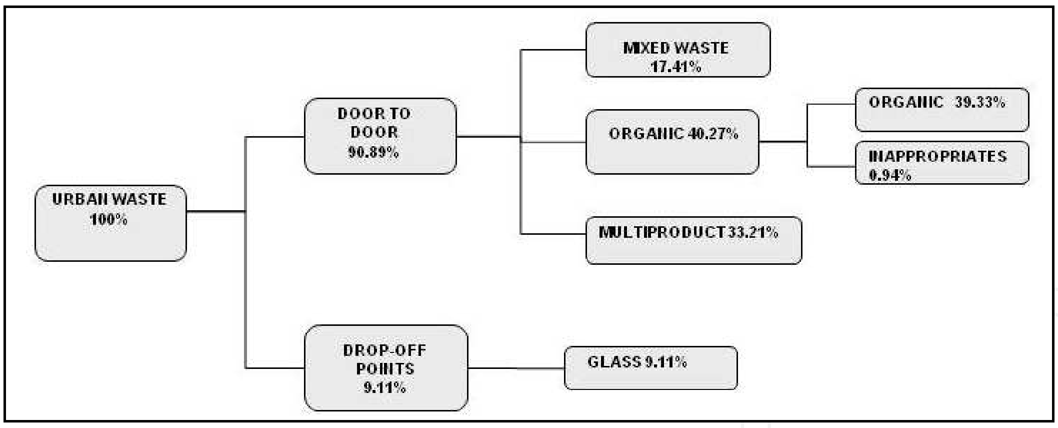


Fig. 11. System E Fractioning Rate

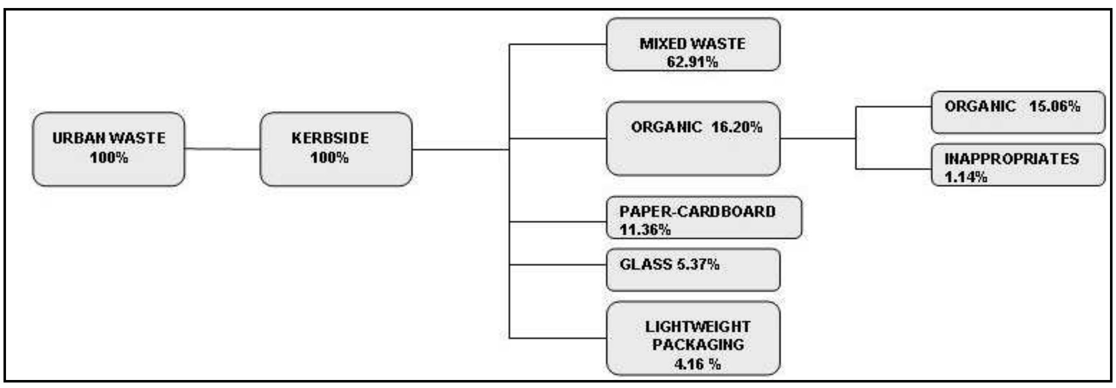


Fig. 12. System F Fractioning Rate

System	A	B	C	D	E	F
QCR_o (%)	68.51	83.82	93.12	90.80	97.67	92.96
SR_o (%)	71.51	24.50	12.92	33.44	76.22	37.85

Table 3. QCR_o and SR_o obtained in each system.

who do participate in this collection do it properly. The reason behind the low QCR_o in system A is the proximity to the mixed waste container, as if the mixed waste container overflows, or even in cases of confusion, mixed waste can be deposited in the organic waste container. The mixed waste container in system A contains approximately 40% of organic waste, meaning that information campaigns are required so that citizens are more aware of this type of collection.

Regarding the SR_o, it can be seen how system E has the highest value, which leads us to conclude that this is the best system. The proximity of the container to the citizen and a higher level of fractioning are undoubtedly factors in obtaining good results in the separate collection of organic waste.

7. References

Adani, F., Baido, D., Calcaterra, E., & Genevini, P. (2002) The influence of biomass temperature on biostabilization–biodrying of municipal solid waste. *Bioresource Technology,* Vol. 83, No. 3, pp. 173-179.

Ayerbe, S. (2000). La recogida selectiva: punto clave para el reciclado, *Proceedings of Seminario sobre cultura medioambiental en la gestión de los residuos urbanos*, Lorca (Spain).

Ayerbe, S., & Pérez, S. (2005). Alternativas para la recogida de envases ligeros, *Ingeniería Química,* No. 423, pp. 203-207.

Belton, V., Crowe, D.V., Matthews, R., & Scott, S. (1994). A survey of public attitudes to recycling in Glasgow (U.K.), *Waste Management and Research,* Vol. 12, No. 4, pp. 351-367.

Berbel, J., Peñuelas, J., Ortiz, J., & Gómez, M. (2001). Análisis comparado de modelos de recogida selectiva de envases/orgánico, *Residuos* No. 59, pp. 52-57.

Blumenthal, K. (2011). Generation and treatment of municipal waste. Eurostat 31/2011 — Statistics in focus.

Bolaane, B. (2006). Constraints to promoting people centred approaches in recycling, *Habitat International, Vol.* 30, No. 4, pp. 731–740.

Connett, P. (2011). Zero Waste: A Key Move towards a Sustainable Society. August 2011. Available from: http://www.americanhealthstudies.org/zerowaste.pdf

Daskalopoulos, E., Badr, O., & Probert, SD. (1998). Municipal solid waste: a prediction methodology for the generation rate and composition in the European Union Countries and the United States of America, *Resources, Conservation and Recycling*, Vol. 24, No. 2, pp. 155-166.

Dahlén, L., Vukicevic, S., Meijer J., & Lagerkvist, A. (2007). Comparison of different collection systems for sorted household waste in Sweden, *Waste Management* , Vol. 27, No. 10, pp. 1298-1305.

Emery, AD., Griffiths, A.J., & Williams, K.P. (2003). In a depth study of the effects of socio-economic conditions on household waste recycling practices, *Waste Management and Research,* Vol. 21, No. 3, pp. 180-190

Gallardo, A., Tejero, I., & Ferrer, J. (1999). Alternativas en la recogida selectiva ante el nuevo marco normativo, *Proceedings of VI Congreso de Ingeniería Ambiental*, Bilbao, February, 1999.

Gallardo, A. (2000). *Metodología para el diseño de redes de recogida de selectiva de RSU utilizando sistemas de información geográfica. Creación de una base de datos aplicable a España*, Universidad Politécnica de Valencia, Valencia.

Gallardo, A., Bovea, M., Colomer, F., Prades, M., & Carlos, M. (2010). Comparison of different collection systems for sorted household waste in Spain, *Waste Management,* Vol. 31, No. 7, pp. 379-406.

Gandy, M. (1994). A comparative overview of recycling in London and Hamburg, *Waste Management and Research,* Vol. 12, No. 6, pp. 481-494

Gilnreiner, G. (1994). Waste minimization and recycling strategies and their changes of success, *Waste Management and Research,* Vol. 12, No. 3,pp. 271-283.

Gomes, A., Matos, M., & Carvalho, I. (2008). Separate collection of the biodegradable fraction of MSW: An economic assessment, *Waste Management* , Vol. 28, No. 10, pp. 1711-1719.

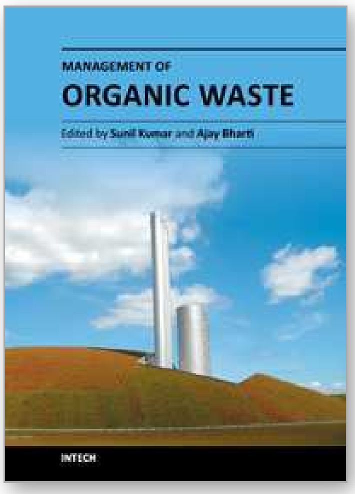
González-Torre, P.L., & Adenso-Díaz, B. (2005). Influence of distance on the motivation and frequency of household recycling, *Waste Management*, Vol. 25, No. 1, pp. 5–23.

Harder, M.K., & Woodard, R. (2007). Systematic studies of shop and leisure voucher incentives for household recycling, *Resouces, Conservation and Recycling,* Vol. 51, No. 4, pp. 732–753.

INE, 2008a. Demografía y población. Cifras de población y censos demográficos, In: *Instituto Nacional de Estadística*, Available from: www.ine.es

INE, 2008b. Sociedad. Análisis sociales, In: *Instituto Nacional de Estadística*, Available from: www.ine.es

Kelleher, M. (1996). Four stream residential collection in Holland, *Biocycle,* October, pp. 46-50.
Kimrey, E. (1996). Rethinking the refuse/recycling ratio, *Biocycle*, July, pp. 44-47.
Lober, J. (1996). Municipal solid waste policy and public participation in household source reduction, *Waste Management and Research,* Vol. 14, No. 2, pp. 125-143
Martin, M., Williams, I.D., & Clark, M. (2006). Social, cultural and structural influences on household waste recycling: a case study. *Resources, Conservation and* Recycling, Vol. 48, No. 4, pp. 357–395.
Marrero, X. (2010). El 5º contenedor llaga a Vitoria-Gasteiz: el reto de los residues orgánicos. *Proceedings of 10 Congreso Nacional de Medio Ambiente (CONAMA)*. Madrid, 2010.
Mattsson, C., Berg, P., & Clarkson, P. (2003). The development of systems for property close collection of recyclables: experiences from Sweden and England, *Resources, Conservation and Recycling*, Vol. 38, No. 1, pp. 39-57.
MCP (1997). *Los envases en la gestión integral de los residuos*. Mancomunidad de la Comarca de Pamplona (MCP). Pamplona
Noehammer, H.C., & Byer, P.H. (1997). Effect of design variables on participation in residential curbside recycling programs, *Waste Management and Research,* Vol. 15, No. 4, pp. 407-427
Perry, G.D., & Williams I.D. (2006). The participation of ethnic minorities in kerbside recycling: A case study, *Resources Conservation and Recycling*, Vol. 49, No. 3, pp. 308-323.
Rojas-Castillo, L.D., Gallardo, A., Aznar, P., Ull-Solis A., & Piñeros, A. (2008). La participación ciudadana en los sistemas de recogida selectiva de residuos urbanos, un factor clave en la gestión, *Proceedings of I Simposio Iberoamericano de Ingeniería de residuos*, Castellón (Spain), July, 2008.
Shaw, P.J., Lyas, J.K., & Hudson, M.D. (2006). Quantitative analysis of recyclable materials composition: tools to support decision making in kerbside recycling, *Resources, Conservation and Recycling,* Vol. 48, No. 3, pp. 263–279.
Tchobanoglous, G., Theisen, H., & Vigil, S.A . (1994). *Gestión Integral de Residuos Sólidos*, McGraw-Hill, Madrid.
UE (2011). Analysis of the evolution of waste reduction and the scope of waste prevention. European Commission. DG Environment. Framework contract ENV.G.4/FRA/2008/0112
Velis, C.A., Longhurst, P.J., Drew, G.H., Smith, R., & Pollard, S.J.T. (2009) Biodrying for mechanical–biological treatment of wastes: A review of process science and engineering. *Bioresource Technology*, Vol. 100, No. 11, pp. 2747-2761.
Wang F.S., Richardson, A.J., & Roddick, F.A. (1997). Relationships between set-out rate, participation rate and set-out quantity in recycling programs, *Resources, Conservation and Recycling*, Vol. 20, No. 1, pp. 1-17.
White, P.R. , Franke, M., & Hindle, P. (1995). *Integrated Solid Waste Management. A lifecycle Inventory*. Chapman & Hall, ISBN 0-8342-1311-7, New York
Wilson, C., & Williams, I. (2007). Kerbside collection: a case study from the north-west of England, *Resources, Conservation and Recycling*, Vol. 52, No. 2, pp. 381-394.
Woodard, R., Harder, M., Bench, M., & Philip, M. (2001). Evaluating the performance of a fortnightly collection of household waste separated into compostables, recyclates and refuse in south England, *Resources, Conservation and Recycling*, Vol. 31, No. 3, pp. 265-284.
Zhang, D-Q., He, P-J., & Shao, L-M. (2009) Sorting efficiency and combustion properties of municipal solid waste during bio-drying. *Waste Management,* Vol. 29, No. 11, pp. 2816-2823.



Management of Organic Waste

Edited by Dr. Sunil Kumar

ISBN 978-953-307-925-7
Hard cover, 198 pages
Publisher InTech
Published online 01, February, 2012
Published in print edition February, 2012

This book reports research on the utilization of organic waste through composting and vermicomposting, biogas production, recovery of waste materials, and the chemistry involved in the processing of organic waste under various processing aspects. A few chapters on collection systems and disposal of wastes have also been included.