UNIVERSITY
OF GÄVLE

DEPARTMENT OF TECHNOLOGY AND BUILT ENVIRONMENT

WORK WITH AGENDA 21 IN EUROPEAN CITIES

A case of study: the waste's management in Barcelona and Gävle

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Abstract

Sweden is a long-term world reference country in terms of sustainable development. On the other hand, Barcelona has recently made great efforts in order to improve and to make society aware of the importance of environmental issues. Hence, it would be interesting to investigate if these efforts had succeeded in the waste's management in Barcelona compared to other leading European cities, and particularly to the case of Gävle.

In this work, the operation of the management of the urban solid wastes of the two cities is explained.
First, the objectives marked by Agenda 21 of each locality are exposed. Next, a theoretical perspective about management, generation of wastes and types of waste treatment is provided. In the following chapter, the results of the generation of wastes, selective collection and the treatments of the wastes are shown for both the cases of Barcelona and Gävle until the 2006.
Finally, the two cities are compared and the results obtained in the management of the wastes are discussed.

The conclusion in this study is that Barcelona has improved noticeable in terms of environmentally safe management of the wastes. This has happened thanks to the efforts of the city council and of the citizens.
But it is still necessary to make a major effort by the inhabitants of Barcelona.

Keywords: Agenda 21, waste management, recycling, urban waste

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1 Introduction

1.1 Agenda 21

In the year 1992 the city of Rio of Janeiro was the scene of the world-wide encounter of Chiefs of State, representatives of governmental and non-governmental organizations, municipal authorities, scientists, technicians and industrialists from 179 countries in the context of the Conference of the United Nations for the Environment and the Development, also well-known as the "Summit of the Earth" [1].
About 2.000 participants and 50.000 assistants of all around the world analysed together the main environmental, social and economic problems that face the humanity. The final objective was to define a joint action strategy for advancing in the construction of an equitable society in balance with the natural environment; that is, a more sustainable development.

The consensus obtained in the "Summit of the Earth" is reflected in a document called Agenda 21 [2].

The Agenda 21 is not only a declaration of principles; it is also a program of actions addressed to face the social and environmental local and global problems of the humanity from a new ethical perspective. Therefore, this is a political top-level commitment for the cooperation.

Two years after the Summit of the Earth, in 1994, Europeans representing local authorities of international organizations, national governments, research centres and individuals met in the Danish city of Aalborg [3].

From this encounter the Letter of Cities and European Towns arose towards the Sustainability. The Letter of Aalborg is a document by which means the European cities were committed to participate in the local initiatives of the Agenda 21 and the development of long term programs that allow advancing towards the urban sustainability.
In Europe, there are already thousands of cities that have joined this process. In addition, numerous networks of sustainable cities have been created to act as coordinated form.

The Agenda 21 Local is a model of diagnosis and formulation of municipal policies of sustainability. Its intention is to evaluate the environmental, social and economic conditions of a municipality in order to initiate, with the participation of all those that integrate the community, an open session, creativity and responses a sustainable model which allows to find the ideal dimension of the city. It is also a process that demands a constant self-evaluation of the results reached from the implemented actions, in order to determine the degree of fulfilment of the objectives and raised challenges.

1.2 Local Agenda of Barcelona

In 1995 the city of Barcelona signed the Aalborg Charter, and like thousands of municipalities around the world, it decided to embrace the principals and values of sustainable development as a part of its governmental strategy. The Aalborg Charter and other international agreements signed by the Barcelona City Council have spurred the city to lead the development of its local Agenda 21 programme while at the same time including sustainability criteria in municipal services and activities.

Barcelona's progress towards sustainability will depend on all the actions that the city's organizations and people manage to implant regardless of how simple and modest such activities may be.
All of these actions are encompassed within a framework of 10 lines of actions [4].

1. To protect natural spaces and biodiversity and to expand urban green areas.
2. To protect the compact and diverse city with high quality public space.
3. To improve mobility and make the city streets a welcoming setting.
4. To reach optimal environmental quality levels and become a healthy city.
5. To preserve natural resources and promote the use of renewable energy.
6. To reduce waste production and promote the re-use and recycling culture.
7. To increase social cohesion, strengthening the mechanisms for equity and participation.
8. To promote economic activity oriented towards sustainable development.
9. To advance the culture of sustainability through environmental communication and education.
10. To reduce the city's impact on the planet and promote international co- operation.

The present document will focus only on the study of the objective number 6, that is, to reduce waste production and promote the re-use and recycling culture.
Within this line of action, Barcelona has marked the fallowing targets:

- Reduce waste to a minimum, especially that resulting from packaging, disposable products and special wastes. The best waste is the one which is not produced in the first place.
- Create waste reduction plans for use in government offices and different economic sectors: commerce, distribution chains, large shopping centres, offices, etc.
- Provide for an equitable distribution of the responsibility for waste, distinguishing between domestically generated waste and commercial waste. Implement tax incentives and ordinances to stimulate waste reduction and selective collection, along with dissuasive measures designed along the lines of "whoever pollutes pays for it," to encourage people to stop polluting (punish the use of plastic bags, reward effective waste sorting for recycling, etc.).
- Stop considering organic leftovers as useless garbage. Spread selective collection over the entire city in order to eventually recover at least 80% of organic material through quality composting and methanisation.
- Avoid excessive, superfluous packaging and foster efficient selective collection systems in order to internalise management costs and environmental impact. Promote returnable and reusable bottles and packages (money back for returning containers, beverage machines designed to encourage the use of one's own glass, etc.).
- What we throw away contains recoverable resources. Improve selective collection to the point of recovering at least 75% of paper and cardboard, 80% of glass and 60% of plastic, metal and mixed material containers. Set a calendar with deadlines for meeting these goals.
- Effect the separate collection of all special-category wastes (bulky objects, oils, toxic or hazardous substances) while bringing these specific collection points as close as possible to the citizen (door to- door collection, neighbourhood shops and small local waste disposal sites) and making information on these services readily available.
- Close down the Garraf landfill for restoration, monitoring its subsequent environmental impact, and replace it with smaller treatment facilities that reduce harmful environmental impact (composting plants, methanisation plants, controlled dumpsites for previously treated waste material, etc.).

- Improve the design of waste-collection objects and apparatuses (household garbage pails, street containers, trucks, etc.) to facilitate the sorting and management of different materials from the kitchen to dumpsites. Incorporate the concept of equal accessibility in the improved designs.
- Develop educational, communication, information, participation and support strategies aimed at getting all citizens to buy into these objectives and adapt their everyday habits accordingly.

1.3 Local Agenda of Gävle

The work in Gävle with the Agenda 21 local began in 1993-94. From that date the municipality took decisions that were of great strategic importance for the municipality. A project manager was employed.

The work began with a call to all the homes, companies and associations by Municipal Council. This way, the municipality made contact with a great number of interested agents.
In 1999 the work group took an operational program for a period of three years, from 2000 to 2002.
Some time after, the 4 of April of 2005, the delegates in the Municipal Council of Gävle decided to tale the objectives for the local environment.

The municipality took the Swedish national objectives for the environment as a base for the local objectives. They also took targets [6] [7].

The 16 national environment objectives are:

1. Reduce climate impact
2. Clean air
3. Natural acidification only
4. A non-toxic environment
5. A protective ozone layer
6. A safe radiation environmental
7. Zero eutrophication
8. Flourishing lakes and streams
9. Good-Quality Groundwater
10. A balanced marine environment, flourishing coastal areas and archipelagos
11. Thriving wetlands

12. Sustainable forests
13. A varied agricultural landscape
14. A magnificent mountain landscape
15. A good built environment
16. Rich diversity of plant and animal life

The action lines that are treated in the present work are within the objective 15: A good built environment. These lines are further described next.

- The quantity and dangerousness of waste are decreasing.
- Waste are separated by categories and recycled on a cooperative basis by residents in urban areas.
- The total quantity of waste generated will not increase and it will be used to a maximum use of its potential resource while minimizing health and environmental effects and associated risks. In particular:
    - The quantity of waste disposed to landfill, excluding mining waste, will be reduced by at least 50% by 2005 compared with 1994.
    - By 2010 at least 50% of all household waste will be recycled through materials recovery, including biological treatment.
    - By 2010 at least 35% of food waste from households, restaurants, caterers and retail premises will be recovered by means of biological treatment. This target relates to food waste separated at source for both home composting and centralized treatment.
    - By 2010 food waste and comparable wastes from food processing plants etc. will be recovered by means of biological treatment. This target relates to waste that is not mixed with other wastes and that is of such a quality as to be suitable, following treatment, for recycling into crop production.
    - By 2015 at least 60% of phosphorus compounds present in waste-water will be recovered for use on productive land. At least half of this amount should be returned to arable land.

1.4 Aim and method

The principal aim of the work is to investigate whether the efforts realized by the city of Barcelona in environmental terms in waste management have succeeded.
The research is based in the comparison with another city.

This city is Gävle because Sweden is a reference country in terms of sustainable development.
For the realization of the thesis, the first step has been reading of literature concerning Agenda 21 and waste's management.

The second step has been the research of the information and data about waste's management of Barcelona. Those data have been obtained through reports in Internet and reports sent by the Secretary of Agenda 21 of Barcelona [4].

The third step has been the research of the information and data about Gävle. All this information is only in Swedish. This information has been translated to English through the web sites. The information of Gävle used during all the work corresponds to 5 populations: Gävle, Hofors, Ockelbo, Sandviken and Älvkarleby [5].

The used data are until year 2006. Internet sites have been an important source of information about waste's management of Barcelona and Gävle. And the translator (systransoft) has been an important tool to understand this information.

Also, personal interviews were conducted in Gästrike Återvinnare and City Council of Gävle, in order to get the information and clarify doubts of the amount of waste collected in Gävle.

Finally, the information has been arranged and compared.

2 Theory

2.1 The cycle of the materials

The waste management is part of what is known as cycle of the materials, which includes all the activities of extraction of raw materials, manipulation or manufacture of products, use or consumption and waste management of this consumption. A block diagram of the cycle of materials is shown in Figure 2.1.1.

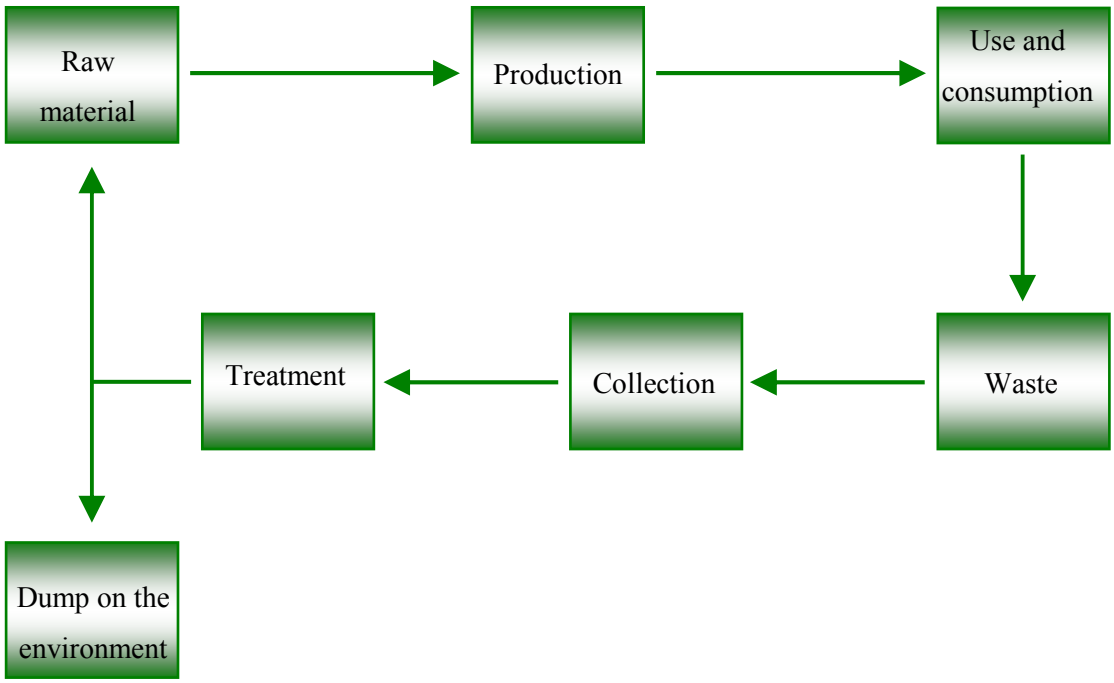

Fig. 2.1.1. The cycle of the materials [10]

The first part of the cycle consisting of the extraction of raw materials, production and use stage and consumption stage, corresponds to the activities that generate the wastes. The second part of the cycle, formed by the collection, the treatment and the spill steps, corresponds to the management of this generated waste.

The cycle of the materials can be open or closed, depending whether the waste is re-introduced in the cycle as secondary raw materials source or if it is dumped into the environment.

Closing the cycle, that is, using the waste as secondary raw materials, it is more

sustainable because it reduces the disposition of waste and avoids the extraction of new materials. Therefore, both factors, reduction of waste and reduction of new materials extraction, contribute to the preservation of the environment.

For this reason, it is very important that the management of the waste favours its exploitation, which can be made through a good system of segregated collection and the correct treatment of each fraction of waste.

However, the total closing of the cycle is not technically possible, since there is always waste that can not be recovered materially. For this reason, it is still fundamental to have systems of recovery of energy from the waste and of controlled deposition.

2.2 Management of waste

The management of the wastes includes all the activities destined to gather and to treat them in a most suitable way, preparing the wastes for the recovery of materials and reintroducing them into the cycle of production, to obtain energy from them, and to dump them in conditions of environmental safety.
Nevertheless, it is more evident that the management of wastes has to include also all the possible actions to anticipate and to minimize its generation.
The most favoured option of managing every waste is the most respectful towards the environment. That is to avoid the pollution, or to avoid extracting more resources.
In this way, the hierarchy for established waste management can be seen in next Figure 2.2.1.

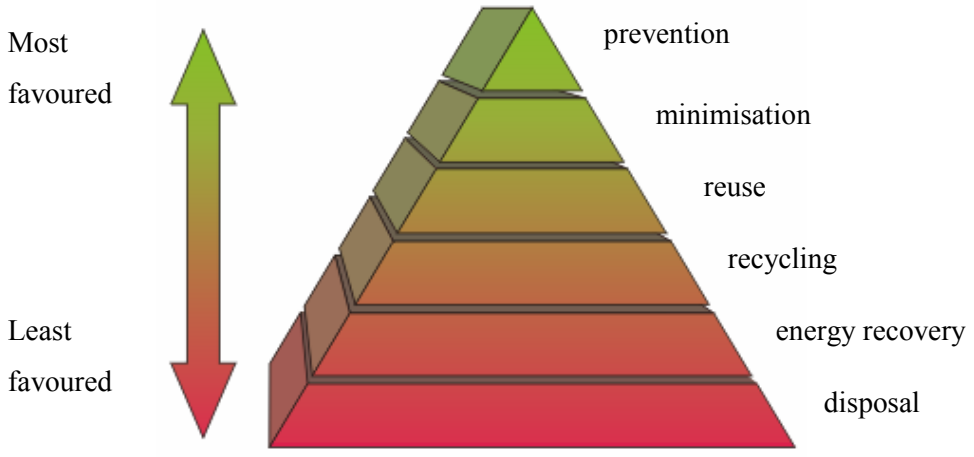

Fig.2.2.1. The hierarchy of the waste [10]

The chosen option will depend on technical conditions, like the quality of waste, the technical feasibility of the recovery of materials and the availability of the necessary infrastructures.

2.3 Generation of waste

The quantity of waste that is generated in the domestic area is related to the characteristics of the economic and cultural system. This influences on the appraisal of the products of only one use and foster consuming habits that favour the utilization of containers and packages.

In spite of the efforts of the administrations in the prevention of waste generation, it does not seem possible to separate the generation from waste of the economic growth. In order to achieve this, it would be necessary to change the consumption patterns towards a model which consists of the consumption of both material and immaterial goods.

The composition of waste, however, has varied substantially in the last decades: the proportion of organic material has always reduced, while the percentage of containers, wrappers and packages has increased.

In spite of the total increase of waste, thanks to the selective collection and to the suitable treatments of each fraction, the amount of materials that are destined to final treatments diminishes progressively.

2.4 Segregated collection

The segregated collection is the system that allows picking up the separate waste fractions in origin and transporting them to the corresponding plants of treatment.

It has two fundamental and complementary goals: on one hand, to sort out and to retrieve the maximum amount of recoverable materials and, on the other hand, to reduce, as much as possible, the amount of waste that is brought to final treatment, like the incineration and the deposit.

It requires the collaboration and the efforts of the citizens, since the environmental

benefits are very important to help and support the quality for the life currently and for the future generations.

2.5 Treatment

The treatment, unlike the collection of waste, is a part often little known in the cycle of management of waste. It encompasses a series of techniques which, applied to the municipal waste, which allow reusing them, recycling them, retrieving energy or stoning them a controlled deposit.
The treatments can be divided into two general types: those which allow the re-introduce from of the materials in the cycle of production and consumption, either for reuse or for recycling, and the final ones, that intend to eliminate the waste, in the safest possible way.

2.5.1 Recycling

Recycling and reusing glass helps to reduce the volume of the municipal waste that must be treated, but also has other environmental benefits. For instance, the recycling of glass allows sparing the raw materials with which the same amount of new glass would be made: a ton of recycled glass spares approximately 1.200 kg of raw materials and entails a decrease in the extraction of its aggregates.

Additionally, the manufacture of new glass consumes more energy than the recycling, therefore, each tonne of recycled glass allows the saving of 100 kg of oil or 1,129 TEP (tonnes equivalent petroleum), with the consequent generalized pollution reduction.

Paper and cardboard picked up selectively reduce the volume of municipal waste, especially the amount of waste to incinerate, which contributes to reduce the atmospheric pollution. Furthermore, the manufacture of recycled new paper from paper pulp is much more ecological because it allows saving between 275 and 450 m^3 of water and from 0, 25 to 0, 45 TEP per ton of paper.

The recycling of two tons of plastic permits saving a ton of oil, while the recycling of a tonne of aluminium allows to avoid the extraction of four tons of bauxite (the mineral from which it is produced) and the production of two tons of which is highly polluting waste and difficult to eliminate.

2.5.2 Biological treatment

The biological treatment can include two types of processes: the composting and the anaerobic digestion. These two processes can be combined; for example, subjecting first the organic material to an anaerobic digestion and making a process of secondary composting. Thanks to these two processes or to their combination of polluting load of waste, the production of leachates and the emission of gases with greenhouse effect are reduced.

This is also a benefit because the organic material can be very pollutant if it is moved to a controlled deposit. On one hand, the action of the rain and of the own physicochemical degradation -so called leaching- can produce a pollutant liquid. On the other hand, methane is generated, which is a very pollutant gas due to its capacity of greenhouse effect.
Moreover, the selective collection of organic material has also other environmental benefits. For example, it allows to generate an organic manure of high quality and to be used in agriculture and gardening. This fact already means a considerable saving by itself, but additionally, it is reducing the use of chemical fertilizers, which can be an important source of pollution for aquatic and for other ecosystems.

Anaerobic digestion

Anaerobic digestion consists of the degradation of the organic material through anaerobic microorganisms. A series of processes gives the production of biogas and the stabilization of the biodegradable waste as a result, so that they are converted in material useful as organic amendments of the ground. The biogas is a renewable source of energy.
The process is carried out in the digesters through controlled changing conditions in about 20 days.

First a process of hydrolysis is applied to the organic material. The goal is to break the cellular membranes and to break down the organic macromolecules, polysaccharides, lipids and proteins, into simpler molecules that can be degraded by microorganisms.

The following step is the acetogenesis, which consists of using these simplest molecules for producing acetic acid, hydrogen and CO_2. In this phase, the microorganisms that participate in it produce exhaust oxygen of the environment, so that the process pioneered in an aerobic way turns to anaerobic.

Finally, in the methane genesis the involved microorganisms use the acetic acid as a source of energy and breathe CO_2 and hydrogen, which gives the production of methane as a result.
The result of all these processes is the production of biogas, a mixture of dioxide of carbon (CO_2) and methane (CH_4) in equal parts, as well as of other side-products in minor amounts. The biogas constitutes a source of renewable fuel that can be useful for generating electricity and heat.
Apart from this product, the remaining organic material has become more stabilized and can be destined for the production of compost, to dump it in a safer way or even to use it as an organic improvement of the ground.

Composting

Composting consists of the degradation of the organic material through aerobics microorganisms. The result of this process is the production of compost or bio stabilized material and of carbon dioxide.
For the process of composting the organic material can be mixed with other materials; for example, with gardening waste or the organic waste of large producers, like markets. In case that waste of pruning and gardening is incorporated, it must be grinded before mixing for facilitating the later decomposition.

The process of composting consists of leaving this mixture of waste to break down initiating the degradation that occurs in the nature, but in an accelerated way. It consists of a controlled bio oxidation process produced by microorganisms that act under determined environmental conditions (temperature, humidity, etc). The process is carried out in impervious compartments, which facilitating its acceleration and, at the same time, avoiding the emanation of smell.

The result is an organic product that, based on its quality, can be used as a fertilizer in gardening and agriculture or for improving soil, infilling, as structuring, etc.

2.5.3 Recovery of energy from the waste

The most implanted systems to recover energy of the wastes are the waste incineration, the fuels derived from waste, anaerobic digestion in plants of biological treatment and catchment of biogas in controlled storage.

Besides the former ones, there are other emerging processes, such as the pyrolysis, the gasification or the plasma technology that also allows retrieving energy from the waste.
The systems of energy recovery have to be reserved for the waste that has not been able to be reused nor have been able to retrieve through processes of material recovery.

Incineration

The incineration is the process in which a controlled combustion is produced with minimum temperatures of 850º C, duration of minimum 2 seconds and turbulence of oxygen superior to 6%.

The fumes that come out of the oven pass through the boiler, where they heat water which, once transformed into steam, it is useful for obtaining electrical energy through a turbine or using it for other uses energy, like the air conditioning (heat or cold) distributed in an urban sector.

As a result of the treatment, the volume of the incinerated waste is reduced by 75% while 20% of inert slag and 5% of ashes are produced.
The slag goes for a vibratory sieve in order to sort out the metals that they can contain. Afterwards they can be used for tasks of infilling of the ground or deposit in a controlled way.
The ashes are accumulated in closed silos until, depending on the harmfulness; they are brought to centres of special waste treatment or poured into controlled deposits for hazardous waste.
Product of combustion and gases are also generated like the carbon dioxide, steam, nitrogen, oxygen (the leftover of the combustion), chlorine, chloride of hydrogen, oxides of sulphur and organic compounds, among other. Before being expelled by the chimney the gases have to fulfil a series of conditions marked by the European valid legislation. For this reason, they pass through an electro filter and a system of washing [11].

The incineration of waste is a treatment regulated in order to limit the environmental impact. The valid legislation establishes very strict parameters regarding the emissions of gases. These parameters are controlled in a permanent and discontinuous way at the exit of gases (chimney), and in periodic way in the case of the ashes.

Fuels derived from waste

In the case of the municipal waste, reference to fuels derived from waste is made when the recovery of energy is made through the combustion of a material prepared for selecting and treating waste that a fossil fuel substitutes.

Anaerobic digestion in plants of biological treatment

The anaerobic digestion consists of the degradation of the organic material through anaerobic microorganisms and gives as a result the production of biogas a renewable source of energy.

Catchment of biogas in controlled storage

The fermentation of the organic material deposited in the dumps generates methane and carbon dioxide. These two gases can be picked up with a system of wells and be profitable as a biogas.

Other treatments

There are other methods of thermal treatment, like the pyrolysis or the gasification. The pyrolysis consists of transforming chemically the waste in absence of oxygen. In the case of the gasification the waste does not burn directly, but it transforms into a combustible gas mixture through a partial oxidation with application of heat.

The difference between the incineration and these processes consists of the presence of oxygen. The incineration implicates combustion in presence of oxygen, while the gasification is made in absence or low concentration of oxygen.

Benefits of the recovery of energy

In general, all the processes of energy recovery, especially the ones of combustion, allow reducing the volume and the weight of the waste that can not be material recovery. Nevertheless, it must be noticed that in the environmental topics, it is always better to prevent, to reuse or to retrieve the waste. Therefore, the energetic recovery has to be the last step in the stages of waste recovery.

2.5.4 Landfill

The controlled deposition is a final treatment that consists of dumping the waste in conditions of environmental security, that is, in a way that they can not be a source of pollution for the environment.

When the waste arrives to the controlled deposit it is positioned on a terrain, previously waterproofed, spreading it on layers of thin and compacting it to reduce the volume. Afterwards, it is covered with a layer of land, which avoids sanitary problems and allows confining itself the waste correctly.
The dumped waste contains part of organic material. This material is fermented and produces biogas (a mixture of methane, CO_2 and other volatile compounds) and leached (liquids resulting from the process of degradation). They both can mean a source of pollution. For this reason, the controlled deposits are structured for minimizing the impacts.

The terrain is waterproofed and a system of catchment and treatment of leached is incorporated into it in order to assure that the leached are not filtered to the ground and not pollute possible aquifers in the zone.
To guarantee that the rain is not filtered inside the deposit and mixed with the leached, there is a system of pluvial waters pipeline.

To avoid the emission of methane at the atmosphere, a system of catchment and treatment of biogas is placed in the deposit.

As last, the waste is poured into cells isolated by layers of compacted land, so that they can come off suitably confined.

It must also be noticed that the controlled deposition is a treatment regulated in a very strict way by the European legislation, and that the waste that is poured has to be previously stabilized, based on to several parameters.

3 Process and results

3.1 Generation of waste

3.1.1 Generation of waste in Barcelona

The generation of waste has increased by some 100.000 tonnes between year 2001 and 2006, and it represents 13% per year. This corresponds to 529 kg per inhabitant and year, that is, 1, 45 kg per person and day. This development is shown in the Figure 3.1.1 and Figure 3.1.2

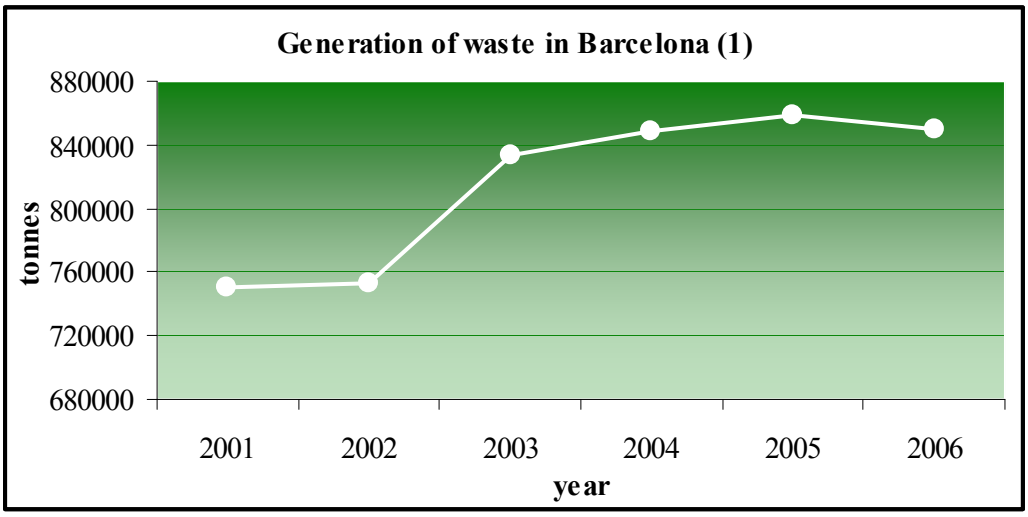

Fig. 3.1.1. Generation of waste in Barcelona [Ajuntament de Barcelona]

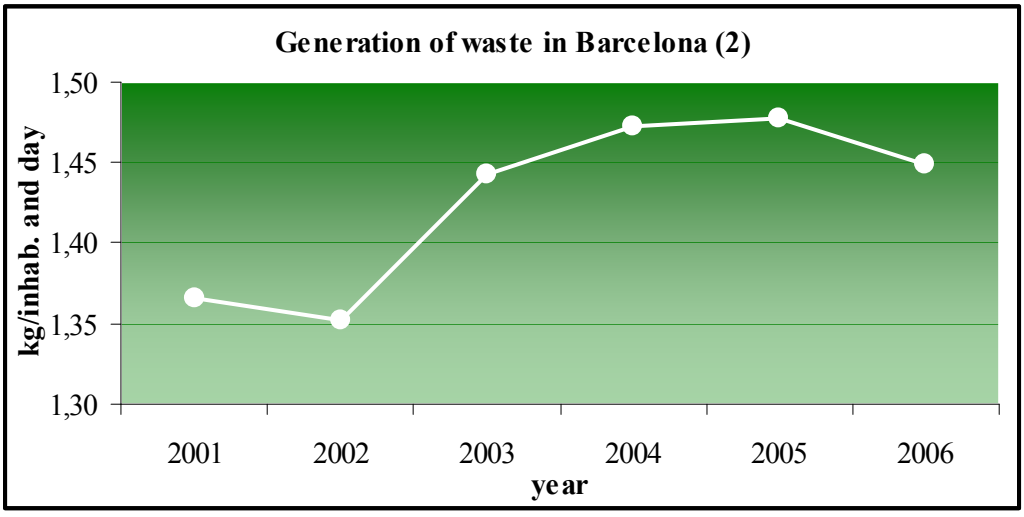

Fig. 3.1.2. Generation of waste in Barcelona per inhabitant [Ajuntament de Barcelona]

3.1.2 Generation of waste in Gävle

The generation of waste has increased by 10000 tonnes between year 2003 and 2006, it represents 15% per year. This corresponds to 555 kg for inhabitant and year, that is, 1, 52 kg for person and day. This evolution is shown in the Figure 3.1.3 and Figure 3.1.4.

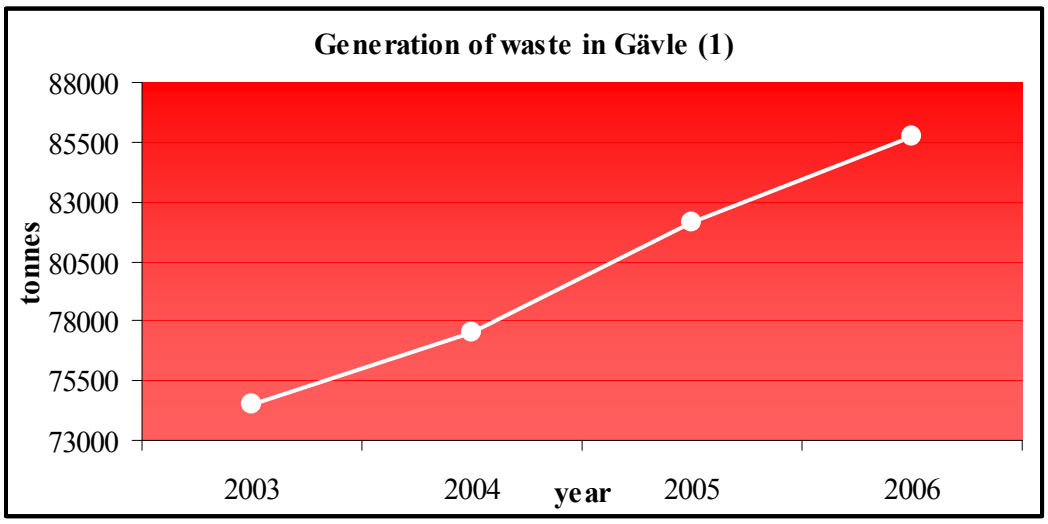

Fig. 3.1.3. Generation of waste in Gävle [Gästrike Återvinnare]

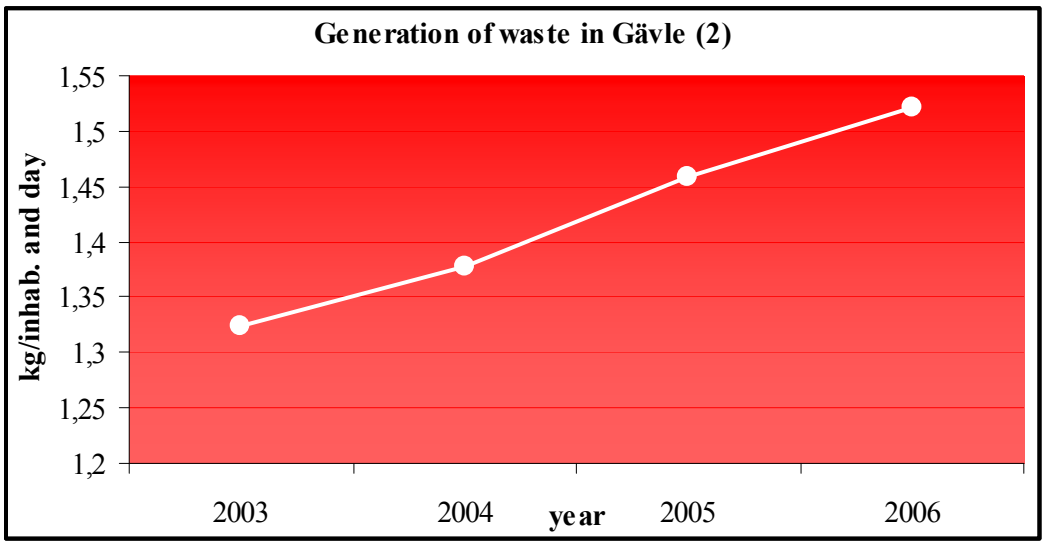

Fig. 3.1.4. Generation of waste in Gävle per inhabitant [Gästrike Återvinnare]

3.2 Segregated collection

3.2.1 Segregated collection in Barcelona

The Town Council of Barcelona implanted the new model of cleaning and selective collection in November of year 2000. It offers services which are more adapted to the needs of every neighbourhood and to the characteristics of every urban space.

The waste is separated in five major fractions: glass, paper and cardboard, light packaging, organic material and mixture.
The glass, the paper-cardboard, the light containers and the organic material constitute the basic fractions of the segregated collection. The materials that have not been correctly selected in origin and some difficult materials of retrieving (pottery, dust, cigarette ends, cotton, etc) they constitute the mixture.
Moreover, there are other types of waste that, for its specific characteristics or because they are generated less frequently, have specific systems of collection.

The selective collection has increased more than the 150% since year 2001. This represents more than 150.000 tonnes of waste retrieved in direct way thanks to the performance of the citizens and of the economic and social sectors of the city. Thus, it has gone from retrieving 67 kg of waste fractions per person and year, in 2001 to pick up more than 160 kg in a selective way in year 2006, see Figure 3.2.1.
The selective collection continues growing, and already is a 31, 5% of the total of generated waste which is shown in Figure 3.2.2 and Figure 3.2.3.

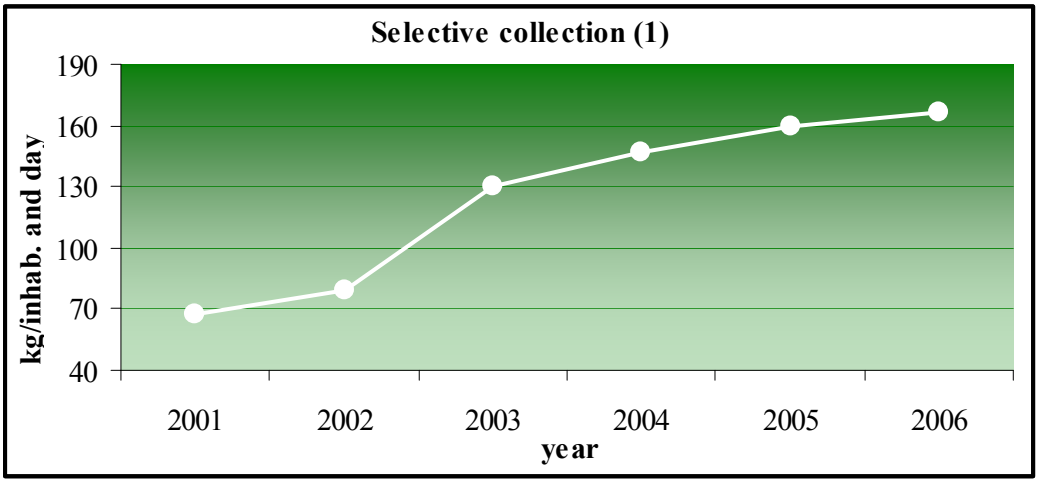

Fig. 3.2.1. Selective collection in Barcelona [Ajuntament de Barcelona]

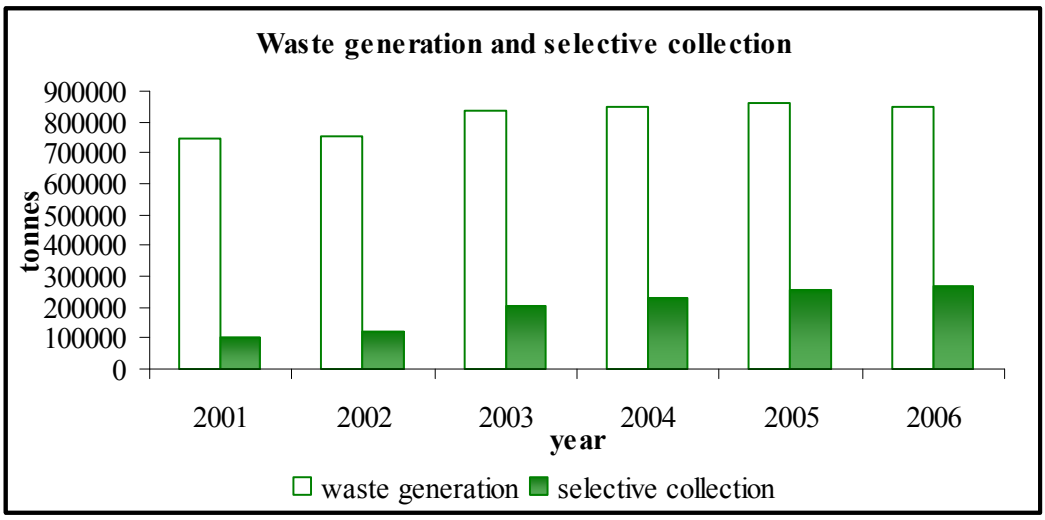

Fig. 3.2.2. Waste generation and selective collection in Barcelona [Ajuntament de Barcelona]

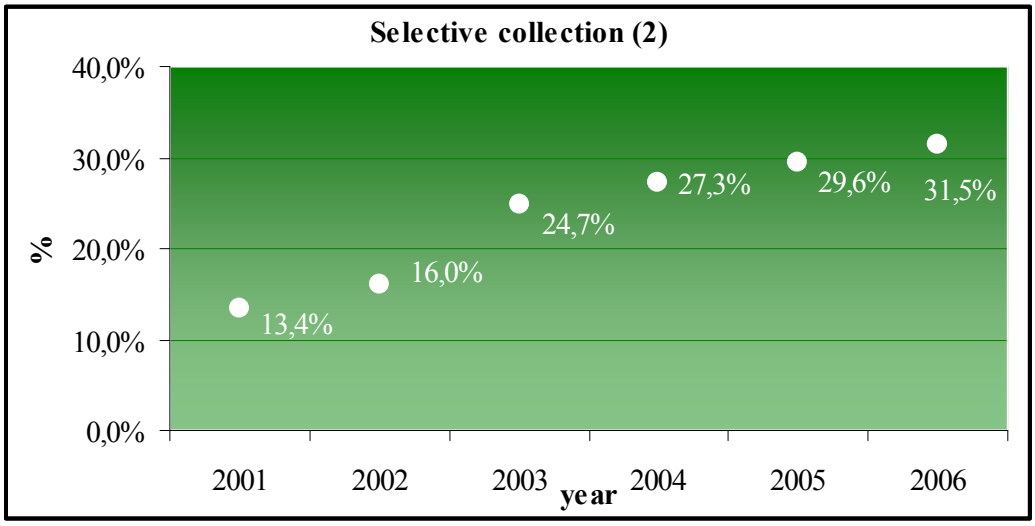

Fig. 3.2.3. Selective collection (%) in Barcelona [Ajuntament de Barcelona]

Glass

On the containers of glass every kind of packing of this material, like bottles, jars and flasks of all colours and sizes, is always picked up without top. The top of plastic and metal have to be brought to the yellow containers.

Glass that comes from other sources, like glasses or broken vases, or especially flat glass do not have to be thrown away; for

Fig. 3.2.4. Container of glass [12]

example, mirrors, windows or tables of glass. They are deposited in the recycling centre.

The glass is collected principally in the containers of type igloo of green colour, placed in the public spaces, see Figure 3.2.4.

It is an important environmental benefit because the glass is 100% recyclable and because it can be reused in average about 40 times.

The segregated collection of glass is one of the first implanted collections: the year 1982 started and the amount of glass picked up continues increasing every year.
The development of the selective collection of glass is shown in the Figure 3.2.5.

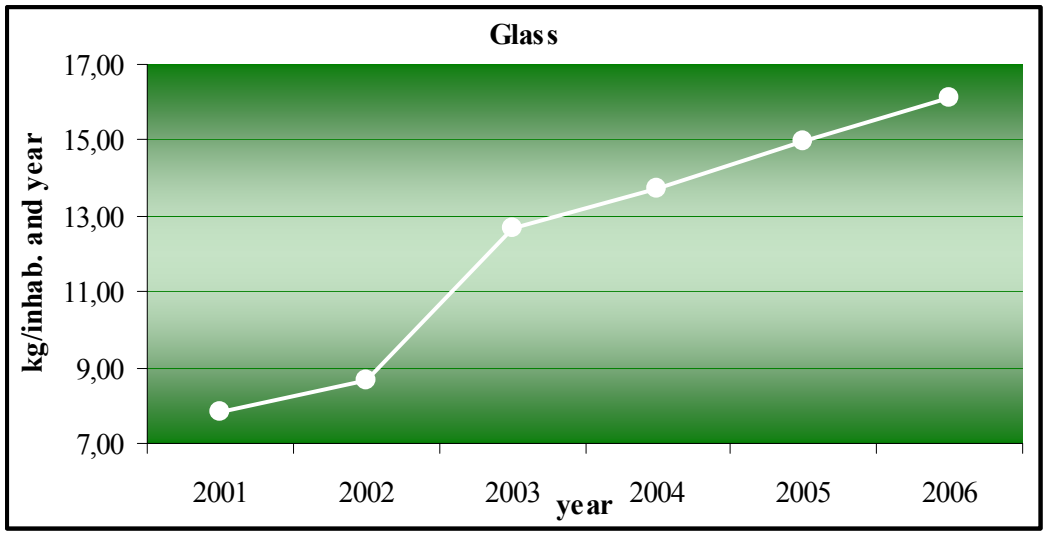

Fig.3.2.5. Selective collection of glass [Ajuntament de Barcelona]

The collection of glass has been 25.901 tons during 2006, a figure that represents an increase of 8, 5 % in relation to 2005, which is a considerable growth despite glass collection which is already well-consolidated.

The ratio of glass picked up by inhabitant and year attains 16 kg, so that an increase of a kilo per inhabitant was achieved in relation to 2005.

Paper and cardboard

The paper and the cardboard is deposited mostly in containers of blue colour, which can be metallic, of igloo type or a lateral load and are placed in the public places, see Figure 3.2.6.

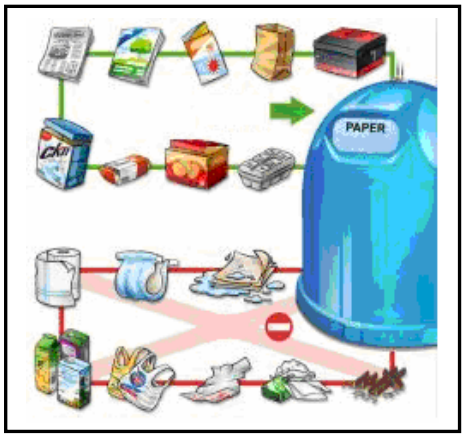

Fig. 3.2.6. Container of paper and cardboard [12]

However, not every kind of paper can be recycled through the containers. There are other complementary systems of collection, like the door collection to door of small commerce shops, in public buildings or in schools.

In the containers of paper every type of paper is picked up, such as white, recycled, paper of printer, newspapers, wrappers of hands soap, magazines or paper gifts. In order to guarantee the maximum level of recycling it is necessary that the paper is whole, without wrinkles.

Every kind of cardboard can also be brought there: packages, packing or shoe boxes. The cardboard has to be thrown folded in three or four flat fragments. In this way, the volume of each container is better used and the collection and the transport are optimized.

It is an important environmental benefit because the segregation of the paper helps to reduce the volume of municipal waste and because it allows making new paper pulp from the paper picked up and the use of vegetal fibres can be spared like this.

Next the development of the collection of paper and cardboard is shown in Figure 3.2.7.

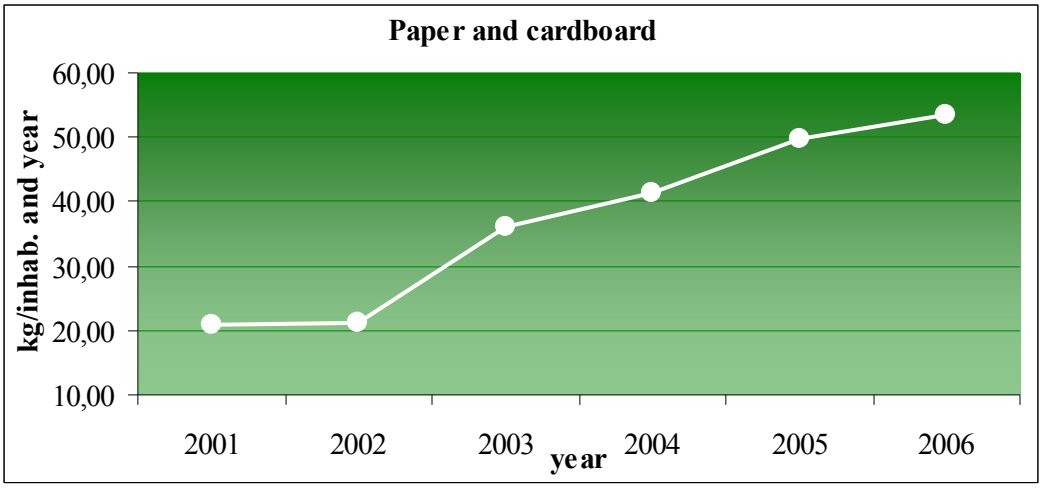

Fig. 3.2.7. Selective collection paper and cardboard [Ajuntament de Barcelona]

The selective collection of paper and cardboard has been up to 85.945 tons, figure that amounts to an increase of 8,5 % in relation to 2005 and in a production per inhabitant and year of 53 kg, almost four kilos more than the year before.

Light packing

The light packing retires mostly in containers of yellow colour, of igloo type and of lateral load and is placed in the public places.

In the containers of packing every kind of packing are picked up (white polyethylene, of colour, FART or PVC), bags, cans etc. For example: bottles of water or milk, containers of detergent or yoghurts, cans of drinks or foods, bricks of milk or wine, bags, trays of porexpan or aluminium foil. It is shown in Figure 3.2.8.

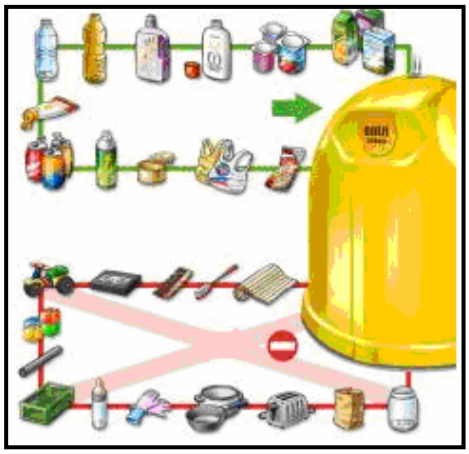

Fig. 3.2.8. Container of light packing [12]

The mixtures of waste of plastic or metal must not be thrown away in the yellow container.

The pens, toothbrushes and other waste that can not be reused have to be thrown away on the gray container of rejection.

It represents an important environmental benefit because the segregation of the containers helps to reduce the volume of municipal waste and because the manufacture of new containers from recycled materials is less polluting.

Next the development of the collection of light packing is shown in Figure 3.2.9

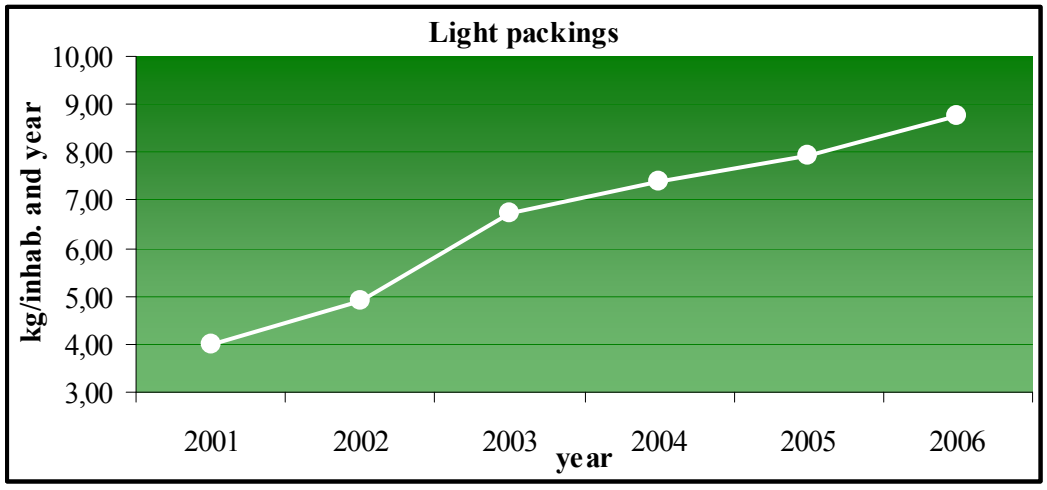

Fig 3.2.9. Selective collection light packing. [Ajuntament de Barcelona]

During 2006, the collection of light packing has increased with 11,25 %. The total production collected for inhabitant and year has been 9 kg.

Organic material

The organic material normally retires on the brown or orange containers that are on the public places. See Figure 3.2.10.

Fig. 3.2.10. Container of organic material [12]

In the containers of organic material every type of waste that can be composted through a fast degradation, as, mixtures of fruit and vegetable, of meat and fish or bread, spoiled solid food, shells of dried fruit and nuts, eggs and shellfish, coffee and infusions, mixtures of plants, withered bouquets and dry flowers, caps of cork, paper of cooking and used paper napkins can be collected. The lawn of gardens and tree leaves can also to be deposited in these containers. (Trunks of pruning must not be thrown into it under any circumstances).

The collection of organic material has up to 2006 been at 53 kg per inhabitant and year, it has increased more than forty kilos in relation with 2001, see Fig. 3.2.11.

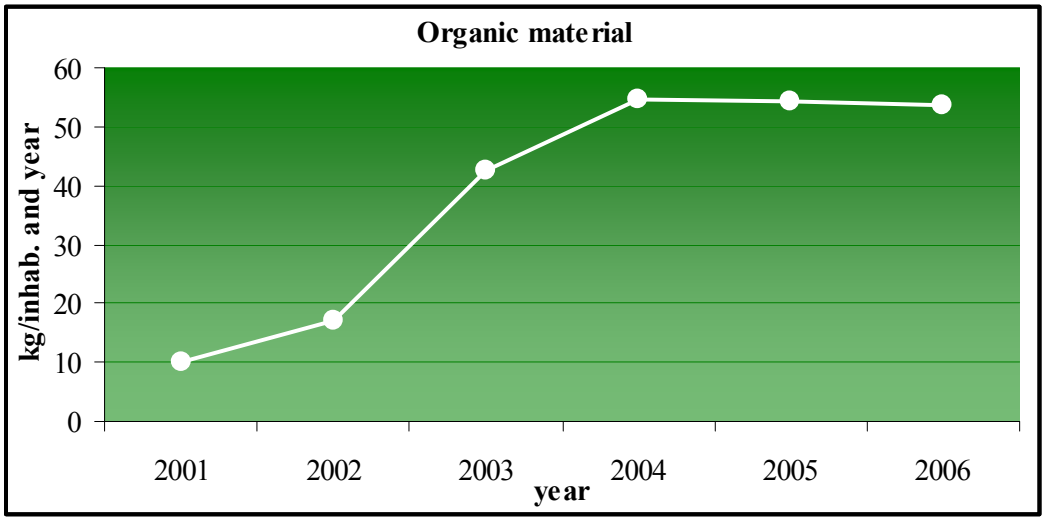

Fig.3.2.11. Selective collection of organic material [Ajuntament de Barcelona]

The mixture

The mixture refers to all waste that remains once the segregation is made of the other fractions (glass, paper -cardboard, light packing and organic material). In spite of this negative definition, it is considered that the mixture is also a segregated fraction, which has to receive a specific treatment.

The mixture is normally deposited in the containers of gray colour that are on the public places. It is shown in Figure 3.2.12.

Fig. 3.2.12. Container of mixture [12]

As a matter of fact, if all the segregated collections were made correctly, it is calculated that this fraction would only constitute about 17% of the municipal waste. Nowadays, however, it still constitutes a quantitatively very important fraction and, therefore, it requires a specific treatment.

The treatment of the mixture represents an important environmental benefit because it allows reducing the waste, the volume and the polluting burden of the waste that ends up to final treatment, to retrieve materials and to generate useful biogas for producing electrical energy.

3.2.2 Segregated collection in Gävle

The domestic garbage is formed by diverse types of materials. The recycling of these different articles, plastic, glasses, metals, papers, newspapers, packing and wastes of electrical and electronic equipments need a certain planning in the houses.

The recycling centres and local sites with containers are placed near the parking's of the supermarkets or in areas near the houses in order that the people could recycle their wastes.

The big recycling centres of wastes offer a range of facilities for articles as glass, paper, scrap and voluminous material, as iceboxes, furniture and wastes of the gardens.

The government has decided that every company that manufactures, imports, fills or sells packaging or packaged goods, should be responsible for the existence of a collection

system where the customers can deposit packaging for recycling. This is referred to as the producer's responsibility. The same applies to newspapers and recycling. Those who manufacture or import newsprint and print or import newspapers will also be responsible for collecting and recycling returned paper. Packaging and newspapers are two of the largest product groups that are subject to producer's responsibility.

The Figure 3.2.13 shows the symbols of the containers for help to recycle.

Fig.3.2.13. Symbols of the containers [13]

The selective collection has increased 39, 8% since 2003. Thus, it has gone from retrieving 253 kg of waste fraction per person and year in 2003 to collect more than 350 kg in a selective way in year 2006, see Figure 3.2.14.

The selective collection continues growing, and is already 63.8 % of the total generated waste which is shown in Figure 3.2.15 and Figure 3.2.16.

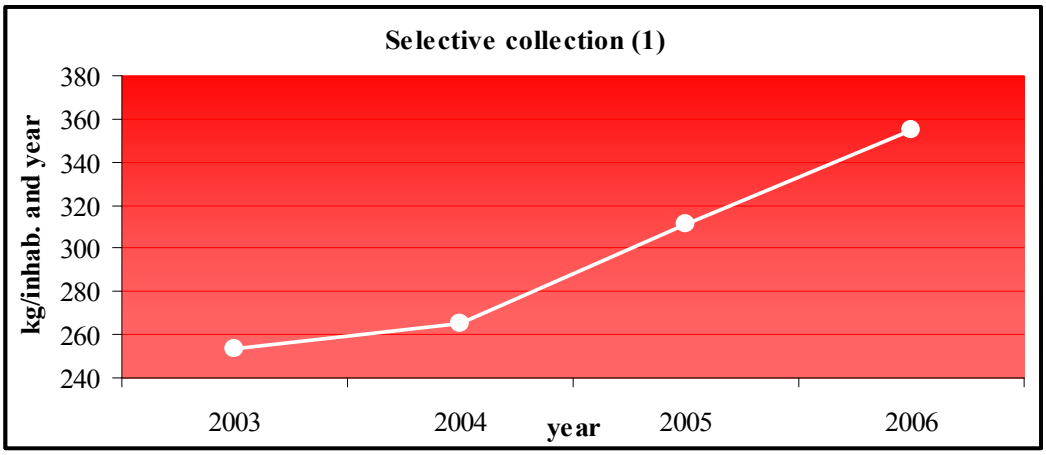

Fig. 3.2.14. Selective collection in Gävle [Gästrike Återvinnare]

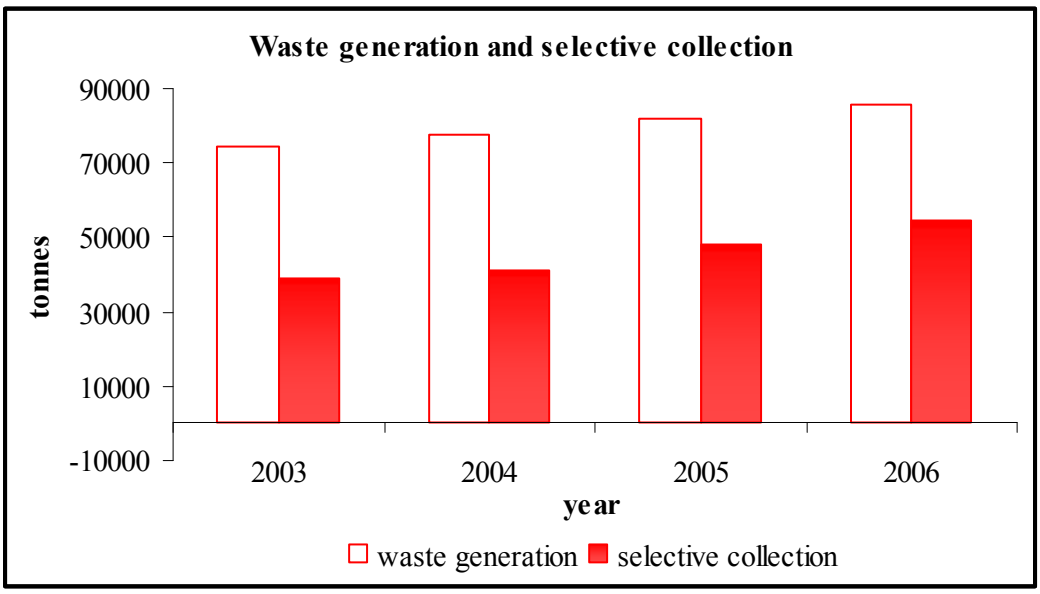

Fig. 3.2.15. Waste generation and selective collection in Gävle [Gästrike Återvinnare]

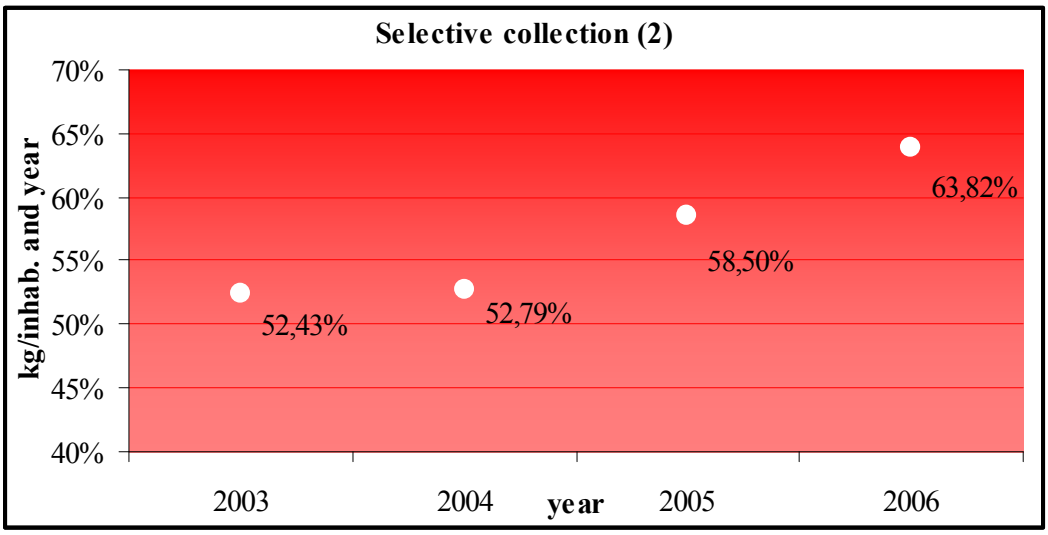

Fig. 3.2.16. Selective collection (%) in Gävle [Gästrike Återvinnare]

The glass packaging

The bottles and the packing's of glass are deposited in different containers, depending whether they are colourless glass or coloured glass which is shown in Figure 3.2.17 and Figure 3.2.18.

Glass that comes from other sources, like glasses or broken vases, not especially flat glass must not be thrown away. For example, mirrors, windows or tables of glass destroy the good recycling.

Fig. 3.2.17. Colourless glass packaging [14]

Fig. 3.2.18. Coloured glass packaging [14]

The selective collection of packaging glass is up to 2.700 tons, figure that amounts to an increase of 14 % in relation to year 2005 and in a production per inhabitant and year of almost 18 kg, two kilos more than the year before which is shown in Figure 3.2.19.

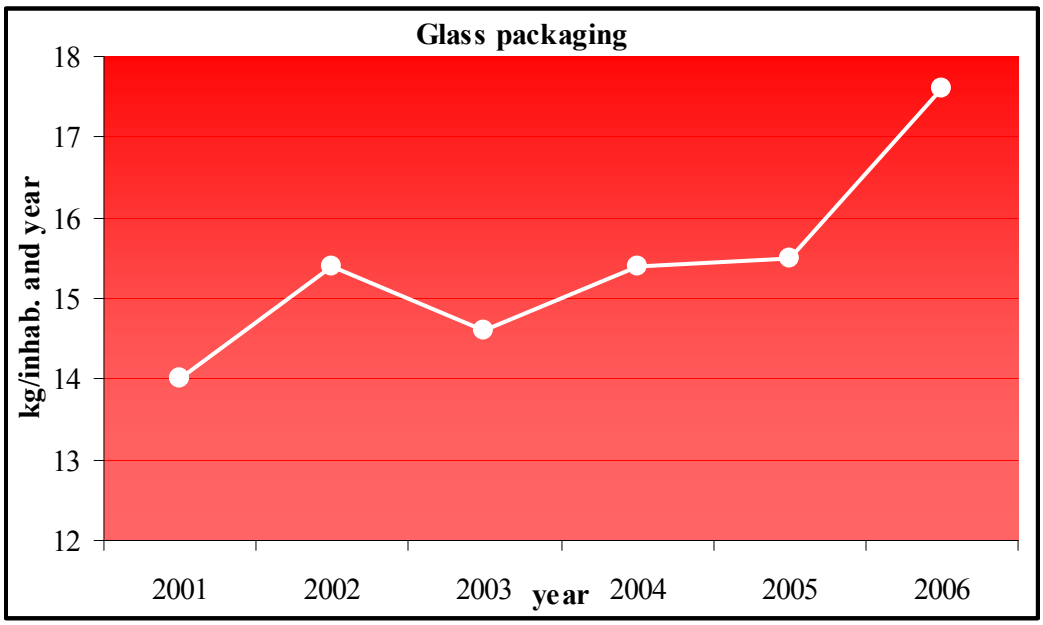

Fig. 3.2.19. Selective collection glass packaging [Gästrike Återvinnare]

Newspapers

The Newspapers, magazines, catalogues, advertising circulars and leaflets are deposited in containers for recycling newspapers, see Figure 3.2.20.

The plastic bags and the sticky labels have to be removed before the papers are placed in

Fig. 3.2.20. Newspapers [14]

the container. Envelopes are placed in household waste.

The newspapers are recycled and it returns as newspapers. The white paper becomes hygiene papers.

In 2006 every inhabitant of Gävle recycled 62 kg of newspapers, see Figure 3.2.21.

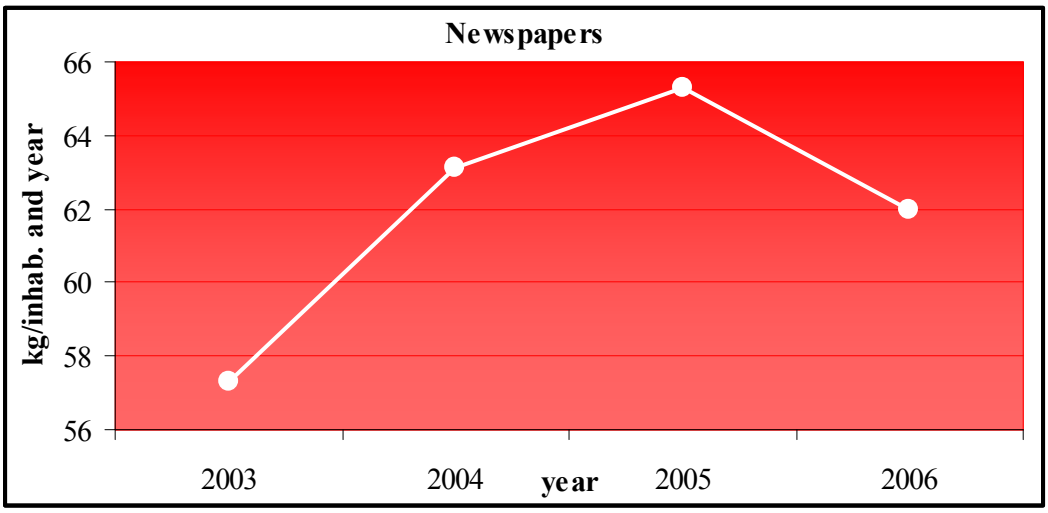

Fig. 3.2.21. Selective collection newspaper [Gästrike Återvinnare]

Paper packaging and cardboard

The dog food sacs, the sugar bags, the pasta boxes, the wrapping paper, the milk and juice boxes, the shoe boxes, the toilet paper rolls and the cardboard boxes have to be deposited in the container for paper packaging which is shown in Figure 3.2.22.

Fig. 3.2.22. Paper packaging [14]

During 2006, the collection of paper packing's and cardboard has been 53 kg per inhabitant and year. That is shown in the Figure 3.2.23.

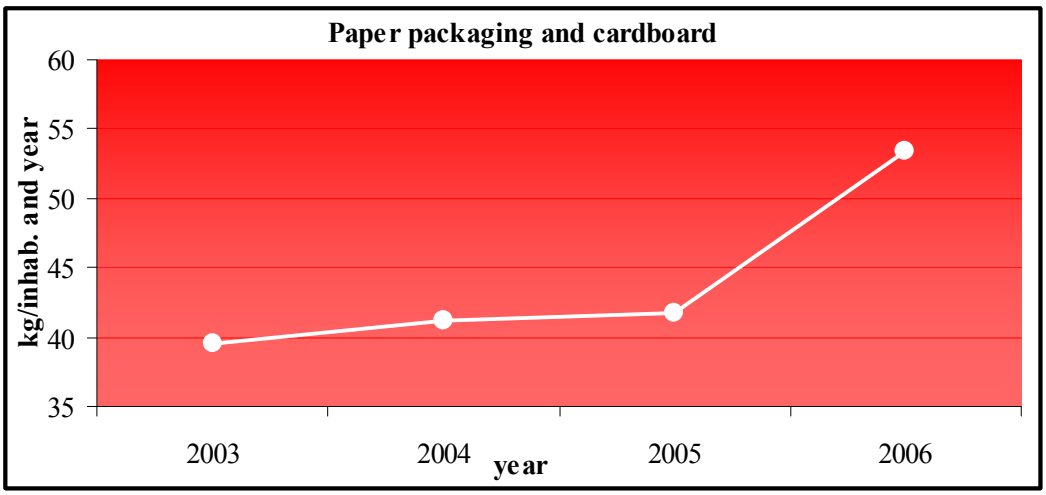

Fig. 3.2.23. Selective collection paper packaging and cardboard [Gästrike Återvinnare]

Hard plastic packaging

Fig. 3.2.24. Hard plastic packaging [14]

The Bottles, the pots and the small buckets have to be deposited in the container for hard plastic packaging, see Figure 3.2.24.

Plastic items (e.g. furniture and toys) that are not considered packaging are discarded as bulk trash or household trash. Refundable plastic bottles should be dropped off at local shops. 90 % of the big bottles of plastic (1, 5 l) and 75 % of the small bottles of plastic were returned to the automatic machines. The machines return the money of the packing of the bottles, see Figure 3.2.25.

The total production collected per inhabitant and year has been 3, 5 kg. It is shown in the Figure 3.2.26.

Fig. 3.2.25. Pictures about selective collection hard plastic packaging [15]

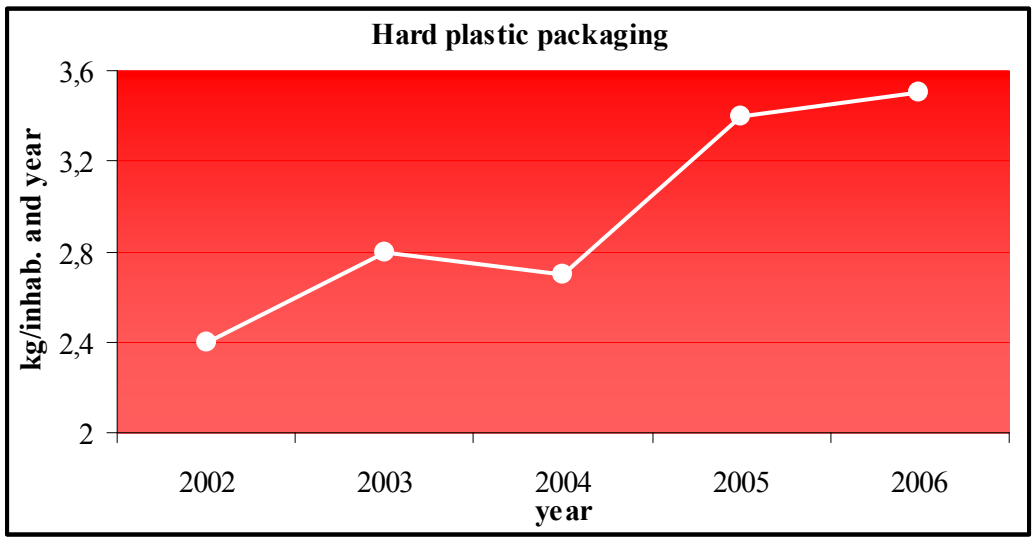

Fig. 3.2.26. Selective collection hard plastic packaging [Gästrike Återvinnare]

Soft plastic packaging

The plastic bags, the refill packages, the plastic wrap and the plastic film have to be thrown in the container for soft plastic packaging, see Figure 3.2.27.

Soft plastic packaging is recycled into new energy. It is either incinerated with other household waste or collected at a recycling station. The total production collected for inhabitant and year has been 4 kg. This is shown in the Figure 3.2.28.

Fig. 3.2.27. Soft plastic packaging [14]

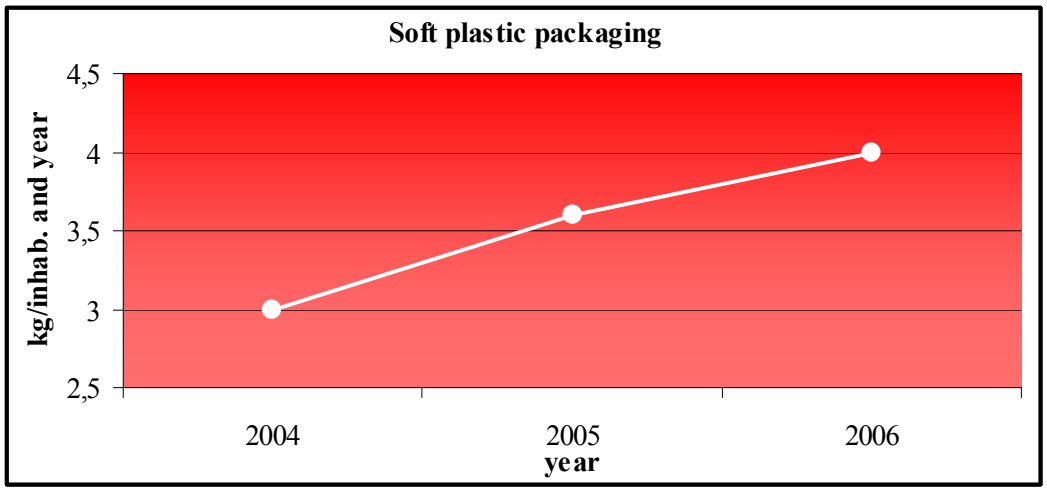

Fig. 3.2.28. Selective collection soft plastic packaging [Gästrike Återvinnare]

Metal packing

The tin cans, the spray cans, the tubes, the bottle caps, the screw tops, the non-refundable soft drink cans, the dried paint cans, the aluminium foil and aluminium products are examples of materials that have to be thrown in the containers of metal packaging, see Figure 3.2.29.

Fig. 3.2.29. Metal packaging [14]

Aluminium tins can be dropped off at shops for a refund. After the use, the tins of aluminium are returned to the special automatic machines that are found in the majority of the food shops. The money is reimbursed to the client. The tins are gathered in sacks and are pressed together, see Figure 3.2.30

The recovery of tins with full deposits is 86 %.

Fig. 3.2.30.. Pictures about selective collection metal packaging [15]

Cans with leftover paint or glue should be discarded as hazardous waste at the central municipal recycling station. Large packages that do not fit into the containers at the recycling station should be dropped off at the central municipal recycling station. Scrap metal, plumbing and heating parts, frying pans and other non-packaging items should be discarded as bulk trash or with the regular household trash.

The total production collected for inhabitant and year has been of 3, 5 kg. It is shown in the Figure 3.2.31.

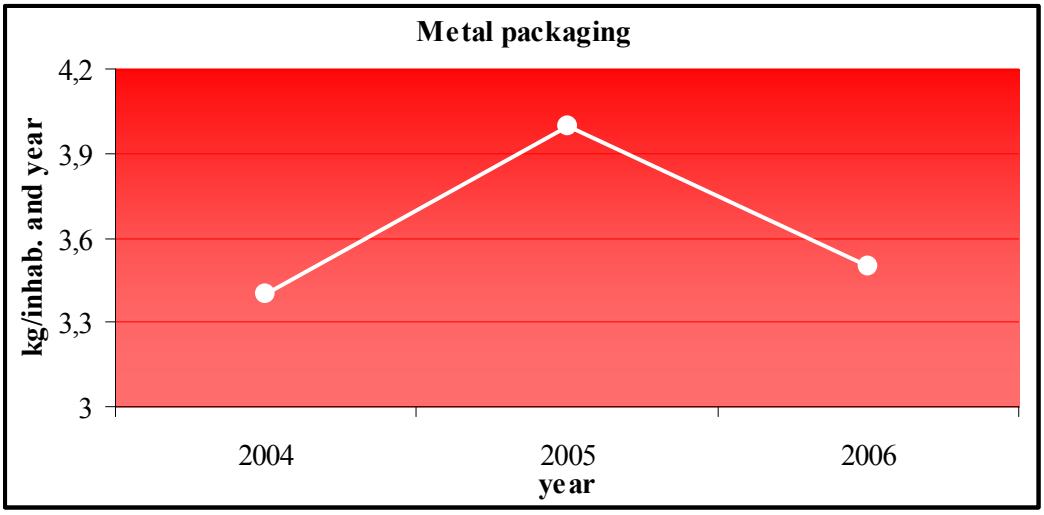

Fig. 3.2.31. Selective collection metal packaging [Gästrike Återvinnare]

Organic material

In many parts of Sweden, households separate their food waste, putting it in paper bags that are collected for composting.

It is necessary to use the sacks that Gästrike Återvinnare provides. It is not possible to use another type of bags. The sacks with remains of food must be thrown inside the brown bin.

Fig. 3.2.32. Organic material [14]

The materials that must be put in the compost sack are leftover food, bones from fish and meat, fruit, vegetable, kitchen paper, paper napkins, bread, cakes, coffee, tea, including paper filters, leaves grounds, flowers, plants, potting soil, ice-cream sticks, wooden toothpicks, popcorn, sweets and chocolate, see Figure 3.2.32.

The materials that must not be put in the compost sack and should go into the household waste are cigarette butts, snuff, nappies, sanitary towels, tampons, cat sand, textiles, vacuum cleaner bags, chewing-gum and ash.

The selective collection of organic material is the one that has increased most during 2006. It goes up to 8.300 tons, figure that shows an increase of 48 % in relation to 2005. The production per inhabitant and year was 54 kg, eighteen kilos more than the year before which is shown in Figure 3.2.33.

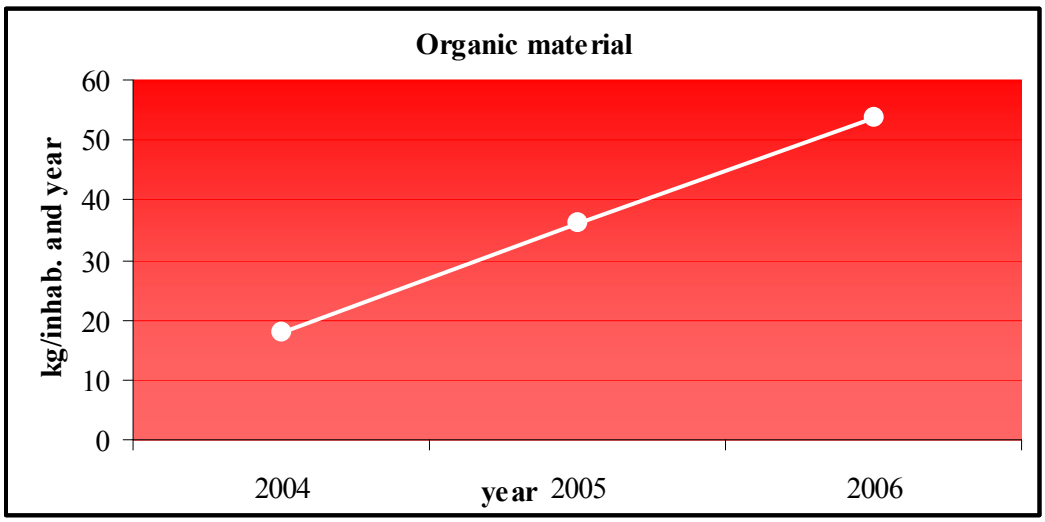

Fig. 3.2.33. Selective collection organic material [Gästrike Återvinnare]

3.3 Types of treatment

3.3.1 Types of treatment in Barcelona

Depending on the waste that has to be treated, where technical or another type is used, but they are always taking into account the material recovery of the waste and the efficiency of the process.

The mixture fraction is taken to metropolitan eco parks which can have three types of treatment.

Type 1: First a pre-treatment of the wastes is realized, and they are separated into three groups of materials: Organic material, retrieved material and rejection. The organic material receives a biological treatment, with production of bio stabilized and stabilized rejection. The second group is recycled and finally the rejection goes to energetic recovery.

Type 2: First a pre-treatment of the wastes is realized, and then they are separated into three groups of materials: Organic material, retrieved material and rejection. The organic material receives a biological treatment, with production of bio stabilized and stabilized rejection. The second group is recycled and finally the rejection is used as a filling material or it goes to deposition directly.

Type 3: First, a pre-treatment of the wastes is realized, and they are biologically stabilized and separated into three groups of materials: Retrieved material, fuel derived from the wastes and rejection. The retrieved material is recycled, the fuel derived from the wastes is used for alternative combustibles and the rejection is deposited in controlled deposits.

The distribution of the waste according to treatment is shown in the Figure 3.3.1 and in the Table 3.3.1.

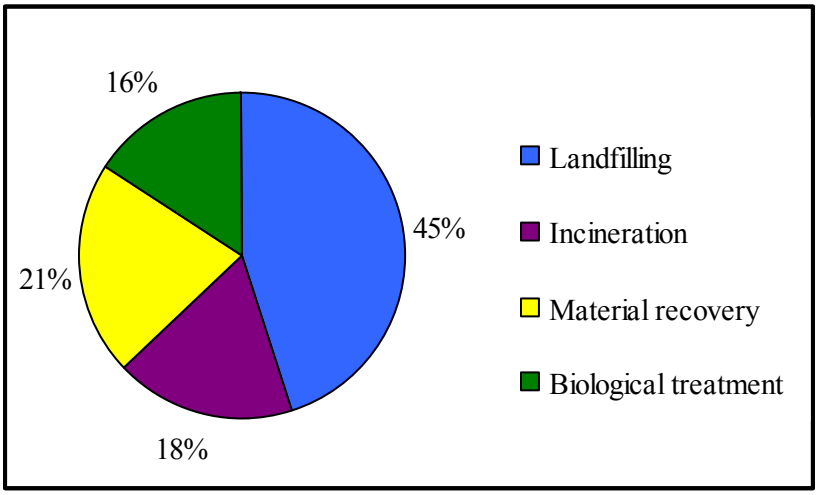

Fig. 3.3.1. Treatment of the waste in Barcelona [Ajuntament de Barcelona]

TREATMENT	quantity (kg/person)	percentage (%)
Material recovery	**112**	**21%**
Biological treatment	**84**	**16%**
Incineration	**95**	**18%**
Landfill	**238**	**45%**
TOTAL	**529**	**100%**

Table 3.3.1. Treatment of waste in Barcelona [Ajuntament de Barcelona]

Recycling

The recovery and the recycling represents 21 % of all waste generated in the houses.

The collection segregated from glass containers is one of the functions of the metropolitan town councils that the Organization of the Environment coordinates and that can be made thanks to the agreements with the integral system of management Ecovidreo [16].
According to the law of packagings, the producers have to be adhered to an integrated system of management of waste, through which the costs of collection and treatment of the glass are funded.
The glass collected by the metropolitan and municipal systems was delivered, without any prior treatment, to two authorised recyclers: Santos Jorge, S.A. and Daniel Rosas, S.A. These companies separate out unsuitable materials (waste that should not have been thrown away in the container of glass like accessories of the bottles, caps and strange bodies) grind the glass and supply the resulting material to glass manufacturers. In 2006 the collected glass was 44 % of the overall production.

The selectively collected paper and cardboard is first sent to a recycling plant (Papeles Allende, S.L., Vilar Vita, S.A. or CESPA, S.A.), which gets rid of unsuitable materials in them before passing them on to the paper mills, thereby increasing their commercial value. In 2006 the collected paper and cardboard was 54 % of the all production.

The separately collected light packaging was delivered to the Gavà-Viladecans sorting plant, managed by SEMESA. During 2006 the plant increased its treatment capacity in order to deal with the waste which until 2005 had gone to the old plant in Sant Feliu de Llobregat. The plant's recovery rate in 2006 was 66 %. In 2006 the collected light packaging was of 12 % of the all production.

Different materials (PEAD, PEBD, PET, PVC, mixed plastics, tetra packs, aluminium and scrap metal, along with smaller amounts of glass and paper) are sorted at the plant and sent to recyclers determined by ECOEMBES. The plant's refuse is taken to a controlled landfill disposal site [17].

Biological treatment

The biological mechanical treatment is the treatment that is applied to the organic material collected and to the mixture before the final disposition.

It consists of sorting out and classifying mechanically the recyclable materials that can have remained in these two fractions, and to treat the remaining organic material through biological processes.
This type of treatment has an increasing importance, because 37% of the weight in total waste is generated in the metropolitan towns is an organic material and it is necessary to prioritize the exploitation. Moreover, in the mixture there can still be a high percentage of organic material that can be selected and treated.
The mechanical part of the treatment consists of sorting out the recyclable elements (metals, plastics, glass, etc) which are to be found in the organic material or the rest.

In order to do it, manual and automatic selection processes are carried out -with ribbons, magnetic elements and sieves, among other-, in a way very similar to that of any plant of selection.

The results of this part of the treatment are, on one hand, to separate recoverable materials for fractions and, the other one, an organic material of which they have been extracted the majority of improper.
In this type of treatment one recovers approximately 5, 6 % of organic material.

The biological part of the treatment can include two types of processes: the composting and the anaerobic digestion.

These two processes can be combined; for example, subjecting first the organic material to an anaerobic digestion and making a process of secondary composting.
Thanks to these two processes or in its combination, apart from the products already mentioned, the polluting load of the waste, the production of leachates and the emission of gases with greenhouse effect is reduced.
Biological treatment of household waste was 16 % of the total household handled waste.
In 2006 the organic material collected was of 27 % of all the production.

Waste to energy

The systems most implanted to retrieve energy from the waste, in the present, are the incineration of waste, the fuels derived from waste, the anaerobic digestion in plants of biological mechanical treatment and the catchment of biogas in controlled deposits.

Incineration accounts for 18 % of the total quantity of treated household waste.
The Ecoparc 3 of the Besòs, placed in the municipal term of Sant Adrià de Besòs, treats the mixture fraction of the municipal waste coming from Badalona, Sant Adrià de Besòs, Santa Coloma de Gramenet and Barcelona.

The Plant of Energetic Recovery is an installation that reduces the volume of the non recyclable waste through the combustion and using the energy of the process, transforming it into electricity or steam for the industry. The resulting materials receive the suitable treatment. On one hand, the ashes and mixtures are object of a controlled disposition, and on the other hand, the smoke and gases are washed and are issued through the chimney once they are cleaned.

In 2006 was incinerated more than 330.000 tons, this is equivalent to the electrical consumption of more than 50.000 families during one year.

Landfill

In 2006, 861.000 tonnes of waste were dumped at the Vall d'en Joan controlled disposal site. Of this, 718.000 tonnes were municipal waste and 143.000 tonnes refuse from treatment plants, waste from municipalities outside the metropolitan area, from businesses and services, etc.
Some 26.000 tonnes of this waste were disposed of in the form of bales. Biogas energy recovery led to the generation of 52.000 MWh. 2006 was the last year this site was in operation. After over 30 years in operation and receiving more than 26.600.000 tonnes of waste, its use as a landfill site came to the end. From now on, however, its environmental impact will continue to be monitored, the biogas from it will still be harnessed and the leachates treated in order to make sure that the site, situated within the Garraf Natural Park, is properly restored.

In line with this approach, the capacity of leachate treatment plant was expanded in 2006 by the introduction of a reverse osmosis process which will make it possible to obtain water fit for clearing roads, cooling engines and maintaining ecological flows.
Landfill accounts for 45 % of the total quantity of treated household waste.

3.3.2 Types of treatment in Gävle

Sweden has a system with three main categories which are the formal responsibility for the management of the waste streams mixture:
- Local authorities (municipalities): responsibility for household waste
- Producers: responsibility for their respective product groups
- Other waste holders and producers (essentially industry and business): where the responsibility does not mixture with the other two categories.

The national environmental quality objectives, as set by the Swedish Parliament, govern waste management and its environmental aspects. One of the objectives is to recycle a minimum of 50 % household waste by year 2010. Last year Gävle achieved a rate of 38 % which included bio waste treatment.

The most important methods of waste handling are:
- Recycling of packaging, waste paper, scrap metal and electronic waste. Recycling lowers environmental impact and saves energy and resources. Recycling through bio waste treatment produces nutrients which can be returned and used as soil enhancers.
- Approximately 43 % of household waste is recycled in Gävle.
- Approximately 51 % of household waste is recovered through incineration. In Sweden the Waste-to-energy incineration yearly produces district heating equivalent to the needs of 700,000 households and electricity equivalent to the needs of 200,000 households.
- Landfills are required for waste that cannot or should not be recycled or disposed of by incineration. Approximately 6 % of household waste is land filled.

This is shown in Figure 3.3.2 and Table 3.3.2.

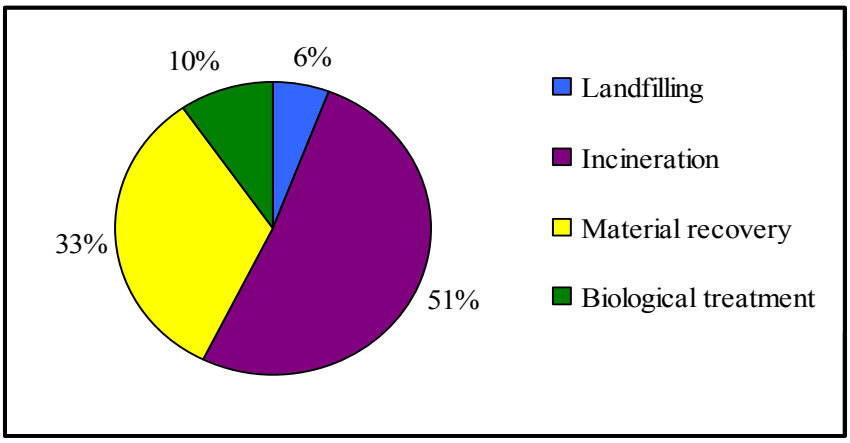

Fig. 3.3.2. Treatment of the waste in Gävle [Gästrike Återvinnare]

TREATMENT	quantity (kg/person)	percentage (%)
Material recovery	**185**	**33%**
Biological treatment	**54**	**10%**
Incineration	**285**	**51%**
Landfill	**32**	**6%**
TOTAL	**555**	**100%**

Table 3.3.2. Treatment of the waste in Gävle [Gästrike Återvinnare]

All the garbage gathered in Gävle is taken to Forsbacka where it is sent to different places of treatment.

Hazardous waste

Small batteries and impregnated wood are included in hazardous waste. In 2006, 5 kg per person of hazardous waste was collected from households.

Hazardous waste can be toxic, carcinogenic, corrosive, mutagenic, environmental hazardous, infectious or flammable. Hazardous substances can be found in very small amounts in a range of products. Adding these together however, these substances can cause great damage especially if they end up in the wrong place. It is therefore vital that hazardous waste is separated from other waste and left for proper and correct treatment.

Local authorities are responsible for handling hazardous household waste. This responsibility encompasses collection, transport and treatment. Municipal authorities are

regulated by the Environmental Code, the Waste Collection and Disposal Ordinance and the Municipal Waste Regulation Ordinance.

Hazardous waste brought into reception points or treatment plants often require pre-treatment in order to simplify the continued treatment process. Since hazardous waste can contain substances which are to be phased out of the ecocycle, the treatment is usually geared towards destroying these substances. Substances which cannot be rendered harmless or re-used are deposited as landfill. It is important that the waste is made chemically and physically stable in order to prevent future leakage.

The last few years have seen great changes in the handling of hazardous waste. New treatment methods have been developed for the recycling of hazardous waste by separating hazardous substances and recycling the remainder.
The method is used, for example, when taking care of paint cans, oil filters and fluorescent tubes. Lead and cadmium can be recycled by melting down batteries. Toxic and slow decomposing substances such as pesticides and other hazardous chemicals are incinerated in specialised furnaces at high temperatures. Polluted soil can be cleansed by biological decomposition. Impregnated wood contains hazardous substances such as arsenic, creosote and copper.

Collected wood is chipped and incinerated in waste-to-energy plants with special licences.

The painting cans are sent to KRYO in Halmstad. There, the painting is separated of packaging. Metal packaging is recovered and the painting is sent to SAKAB in Kumla and Komminkemi in Denmark for the incineration [18].

Mercury batteries are sent to SAKAB AB, which processes the mercury contained in them. Importers of batteries that contain mercury are required to pay a fee to this fund. SAKAB AB will recover 98 % of the mercury. According to one proposal, the recovered mercury will be safely disposed of in an underground repository. Nickel-cadmium batteries and nickel metal hydride batteries are transported to SAFT AB in Oskarshamn. There both cadmium and nickel are recovered.

Recovered cadmium is employed in the manufacture of open nickel-cadmium batteries for industrial use. The recovered nickel goes to steel mills. Nickel metal hydride batteries

contain nearly 50 % nickel, and there are companies interested in salvaging these batteries for their metal value.

The lead-acid batteries are taken to Boliden Bergsöe in Landskrona for reprocessing. Recovered lead is sold to manufacturers of lead-acid batteries, among others. Lead is a serious environmental problem and will be phased out of the material cycle in the long term. But there is no alternative to lead today in applications such as starter batteries for cars.

Alkaline batteries and manganese dioxide batteries are disposed of in landfills for the time being.

Waste from electrical and electronic equipment

Some 20 kg per person of waste electrical and electronic equipment (WEEE) were collected in 2006. Since the producers' responsibility was introduced in 2001, local authorities and producers have cooperated in the handling of WEEE. This collaboration means that local authorities have assumed responsibility for the collection from households whilst the producers handle the treatment.

WEEE from households is collected in recycling centres.
WEEE undergoes pre-treatment; it is sorted or dismantled before it is sent on for further treatment. The waste is mostly dismantled manually by a certified company and then sent on for final treatment or recycling.

Approved plants handle components containing dangerous substances i.e. hazardous waste. Plastic casings are incinerated in waste-to-energy plants and metals are sent to be melted down for recycling. Fluorescent tubes and low-energy bulbs contain mercury. These products are therefore separated and handled in a closed process. Glass and metals can be recycled whilst the majority of the fluorescent powder with its mercury content is taken care of.

The low energy lamps are sent to H A Sopor in Meråker in Norway. There, the glass is crushed and the glass in regained. The mercury is taken away and be intercepted in a special oven. The metal is regained and the mixture is burnt up. The mercury is driven to Oslo where it is put for final disposal.

Fluorescent lights are sent to Denmark to classify. After class is regained 98% of the fluorescent light and the material are sent to fluorescent lights' factories that do new fluorescent lights.

Computers and other electronics are sent to Kooperativet Gävle. There, they are taken into pieces and are classified. The dangerous waste is sent afterwards SAKAB in Kumla. There, the dangerous waste is burned in an oven in 850 degrees. The dangerous steams are taken away with smoke gas purification. Slag and ashes are carried to the final disposal for dangerous wastes

The refrigerators and the deep freezes are sent to Bjästa in Örnsköldsvik. The dangerous waste is treated in Kumla. The metal recovers as scrap iron of the metal and plastics are incinerated.

Electrical appliance, except the fridge and freezer, are driven at the centre of electronic recovery. The printed circuit board is sent to Rönnskärsverken for recycling. The metal is taken to Hallstahammar where it becomes new raw material.

Recycling

Recycling of packaging, waste paper, WEEE and bulky waste collected at municipal recycling centres amounted to 141 kg per person in 2006. That is the equivalent of 28 % of treated household waste.

The paper packaging is driven to Fiskeby paper industry or Örebro, where they become to new boxes.

In 2006 it was gathered more than 83 % of all the newspapers. In 1997 already 75 % was reached. The newspapers are moved to Hallsta's wastebasket where they turn into new papers.

The metal is transported to an installation of classification in Borlänge or Huddinge. Then the clean metals are transported to the workshop of melting. Recycled steel and aluminium is used in packaging, new cars and in buildings.
Recycling of metal packaging has not yet reached its target of 70 %. In 2006, it was 66 % of the quantity sold on the market.

The hard plastic packaging is carried to Swetec in Bredaryd for classifying it. The material is sold to the companies that produce new plastic raw materials.

The coloured glass as well as the colourless is carried separately to the plant of glass of Sweden in Hammar. The glass is classed and it is crushed to be able to use it as new raw material again.
92 % of glass packaging was recycled in 2006. The majority of recycled glass is used in the production of new glass or in other products such as fibre glass. This result exceeds the target of 70 %

The system of deposits on beverage cans of aluminium and PET bottles achieves a high recovery rate. According to Returpack, which is responsible for the deposit system, 86 % of both cans and PET bottles are recycled.

Metal scrap is sent to Stena-Gotthards in Hallstahammar where the metal becomes new raw material. Then, the metal is sent furthermore to melted agencies, where it becomes new metal products.

In the Table 3.3.4 is shown the quantities of material recovery.

Material recovery	quantity (kg/person)
Newspapers	62
Paper packaging and cardboard	54
Glass packaging	18
Metall packaging	3,5
Hard plastic packaging	3,5
WEE	20
metall scrap	24
TOTAL	**185**

Table 3.3.3. Material recovery in Gävle [Gästrike Återvinnare]

Biological treatment

The compost sacks are driven to a composting plant in Forsbacka where it is mixed with shredded park and garden waste. This mixture is placed in large containers with lids, where the waste undergoes composting for three weeks. The mixture is then moved to a

container with no lid, where further composting takes place for four weeks. It takes up to a year before the soil is ready to use. The decomposed, finished compost material is transformed into a useful resource: a good fertiliser to improve the soil in flowerbeds and gardens or be ploughed back into farmland.

Biological treatment of household waste increased with 48 % compared to 2005. In total 8.300 tons was treated in 2006 which is comparable to 54 kg of green waste and food waste per person. Household waste handled through biological treatment stands with 10 % of the total household waste handled. It is in Table 3.3.4.

Biological treatment	quantity (kg/person)
Compost	29
Garden waste	25
TOTAL	**54**

Table 3.3.4. Biological treatment [Gästrike Återvinnare]

Waste to energy

For Gävle as a whole, over 285 kg of household waste per resident was incinerated in 2006. Incineration accounts for 51 % of the total quantity of treated household waste.

Some of the plants also store waste, often through baling, for a period of time during the year. The waste can then be incinerated during the colder part of the year.
Well developed district heating systems in connection with waste-to-energy incineration plants give Sweden a unique advantage compared to many other European countries. Heat recovered from waste-to-energy incineration corresponds to about 20 % of the total need for district heating in Sweden.

The soft plastic is transported to Uppasala where they are incinerated and the heat extracted is in use for district heating.
Flammable is sent to Uppsala, Avesta or Bollnäs and becomes to district heating.
The wood is burned in the heat Agency of Johannes in Gävle.
The quantity of incinerated waste is shown in the Table 3.3.5.

Incineration	quantity (kg/person)
Intermixed waste	201
Flammable	35
Wood	45
Soft plastic packaging	4
TOTAL	**285**

Table 3.3.5. Incinerated waste [Gästrike Återvinnare]

Landfill

The amount of household waste deposited as landfill in 2006 was 32 kg per person. In 2006, 6 % of household waste was deposited as landfill.
The amount of waste deposited as landfill has continuously decreased since 1994.

In Sweden during 2006, landfill gas was recovered at about 60 sites. From the recovered gas an equivalent of 261 GWh was used for heating and 21 GWh was used for electricity. Gas equivalent to about 60 GWh was flared. Flaring does not yield any energy but it does reduce the emissions of hazardous substances.

During the last thirty years operations on landfill sites have developed significantly. At most modern landfill sites, nowadays operations include much more than just landfill; such as the sorting of waste for treatment, transport on to recycling and recovery and also energy recovery on site. Sometimes the sites are also used for storage of large amounts of waste such as paper and glass which falls under the responsibility of producers rather than municipal/household waste.

The quantity of land filled waste is shown in the Table 3.3.6.

Landfill	quantity (kg/person)
Impregnated wood	4,5
Landfill	10,5
Not recycling	17
TOTAL	**32**

Table 3.3.6. Landfilled waste [Gästrike Återvinnare]

4 Discussion

4.1 Generation of waste

The evolution of waste's generation of Barcelona and Gävle from 2003 can be observed in the Figure 4.1.1.

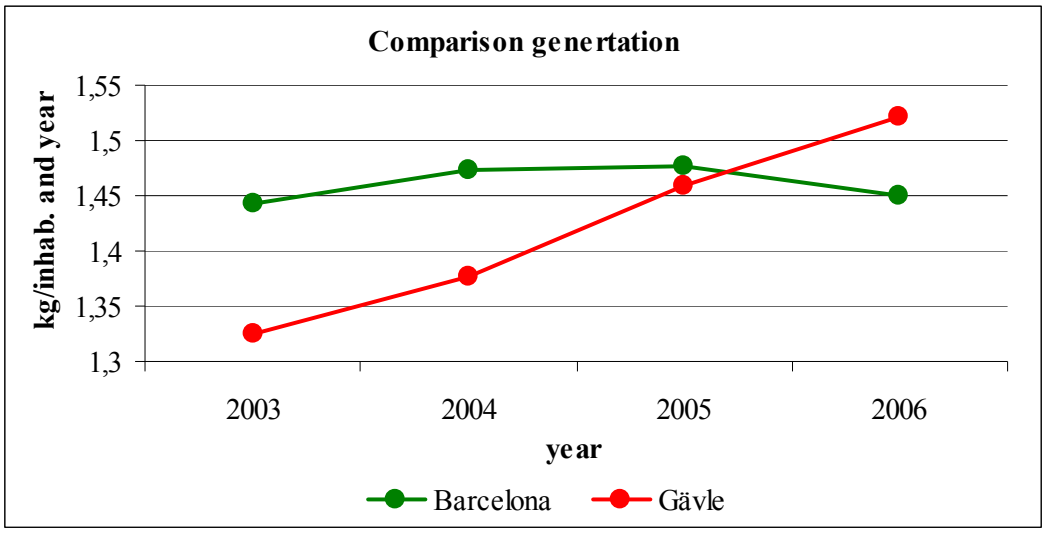

Fig. 4.1.1. Comparison of the waste generation [Ajuntament de Barcelona] [Gästrike Återvinnare]

In 2003 Barcelona's inhabitants generated a 9 percent more wastes than the inhabitants of Gävle. Nevertheless in the 2006 the difference is a 4.8 percent more in Gävle than in Barcelona.

The generation of residues in Barcelona in the last three years has been constant, where as in Gävle it has increased.

This is due to the constant campaigns that the town council of Barcelona realizes. Thanks to these campaigns, schools, universities, associations, private and public companies join the civil commitment in order to reduce the generation of residues. For example, in the bars of the universities the cups are of glass.

In the 2006 the amount of wastes generated by the inhabitants of Barcelona and Gävle are very similar. It is shown in the Table 4.1.1.

	Barcelona	Gävle
Tonnes	**849.332**	**79.031**
kg/ inhab. and year	**529**	**555**
kg/ inhab. and day	**1,45**	**1,52**

Table 4.1.1. Comparison of waste generated in 2006 [Ajuntament de Barcelona] [Gästrike Återvinnare]

4.2 Segregated collection

The waste fraction in the origin is very different between the two cities. Barcelona separates mainly in 5 fractions. Gävle separates in 9 different fractions. In addition to the already mentioned fractions, in the recycling centres of both cities are also collected voluminous waste, electronic devices and dangerous wastes. These fractions are shown in the Table 4.2.1.

Barcelona	Gävle
Paper and cardboard	Paper packaging
	Newspaper
Glass packaging	Uncoloured glass packaging
	Colour glass packaging
Light packaging	Metal packaging
	Hard plastic packaging
	Soft plastic packaging
Organic material	Organic material
Mixture	Mixture

Table 4.2.1. Fractions of selective collection [Ajuntament de Barcelona] [Gästrike Återvinnare]

The waste fractions are only different in the origin, because in the end the two cities separate equal. This is one facility more that the city council of Barcelona offers to the citizens.

The inhabitants of Gävle not only separate in more fractions in origin but also separate more quantity of garbage. In Table 4.2.2, the amount of collected garbage is broken down in the different fraction.

In Gävle they separate 63, 8 % whereas in Barcelona only 31, 5 %.

This difference is mainly due to the fact of the effort, the participation and the conscience of the care of the environment of the inhabitants of the different cities.

In Barcelona the segregated collection increases year after year, but even it is necessary to have a major conscience and a major effort for the next years.

Barcelona	kg/inhab. and year	Gävle	kg/inhab. and year
Paper and cardboard	54	Paper packagings and cardboard	53
		Newspaper	62
Glass packaging	16	Glass packaging	18
Light packaging	9	Metal packaging	4
		Hard plastic packaging	4
		Soft plastic packaging	4
Organic material	54	Organic material	54
Recycling centres	34	Recycling centres	113
TOTAL SEPARATED	**166**	**TOTAL SEPARATED**	**354**
TOTAL GENERATED	529	TOTAL GENERATED	555
% SEPARATED	**31,5%**	**% SEPARATED**	**63,8%**

Table 4.2.2. Comparison selective collection [Ajuntament de Barcelona] [Gästrike Återvinnare]

The Town Council of Barcelona offers many facilities to the citizens to obtain maximum participation to the recycling. Other example of this fact is the Mobile Green Points,that can be seen in Figure 4.2.1.

The Green Mobile Points is a service of selective garbage collection of the Town Council formed by a few trucks that cross the city to fulfil all the functions of a Green Point, but mobile. The Green Points are environmental facilities where to take certain wastes in order that they are distributed to the plants of specific treatment, to recycle them or to

prevent them from contaminating. They take charge of the receipt and of the selective storage of the municipal wastes.

Fig. 4.2.1. Mobile Green Point [19]

Another example is the garbage of furniture and utensils. Every street of Barcelona has assigned a fixed day at the week for the garbage of furniture and utensils collection. The only thing that is necessary, it is to leave the garbage in front of the door of your house between the 20 h and the 22 h the day that corresponds to your street.

In Sweden there are also initiatives to foment the recycling such as the aluminium tins and the plastic bottles settle in the automatic machines that exist in the supermarkets. For every tin or bottle they return back the money of the packing that initially has been paid in the purchase of the product. Sweden has obtained a new record in recycling aluminium tins and plastic bottles see to Figure 4.2.2.

Fig. 4.2.2. Machines of returnable packaging of plastic bottles [20]

4.3 Treatments

Barcelona and Gävle have aims to increase the percentage of garbage that recovers or that does a biological treatment. At this moment, the recovered material including the biological treatment in Barcelona is approximately 37 % and in Gävle is about 43 %. The actual rate recovery of each kind of material and the desired or objective rates are shown in Table 4.3.1 and Table 4.3.2, for the city of Barcelona and the city of Gävle respectively.

	Wasted collected in Barcelona		Aims
paper and cardboard	54%	<	75%
glass packaging	44%	<	80%
light packaging	12%	<	60%
organic material	27%	<	80%

Table 4.3.1. Recovery material and aims of Barcelona [Ajuntament de Barcelona]

	Wasted collected in Gävle		Aims
paper packaging and cardboard	72%	>	65%
glass packaging	92%	>	70%
plastic packaging	68%	<	70%
metal packaging	66%	<	70%
newspaper	83%	>	75%
organic material	18%	<	35%

Table 4.3.2. Recovery material and aims of Gävle [Gästrike Återvinnare]

Barcelona is still far from the aims that have been marked for the future. On the other hand, Gävle exceeds in many fractions their own marked future objectives.

In Table 4.3.3, a great difference between the wastes that are incinerated and those that go to the dump can also be seen. Another important objective is to reduce as much as possible the wastes that go to landfills.

	BARCELONA	GÄVLE
Material recovery	21%	33%
Biological treatment	16%	10%
Incineration	18%	51%
Landfill	45%	6%

Table 4.3.3. Comparison of treatment [Ajuntament de Barcelona] [Gästrike Återvinnare]

In Barcelona, the biological treatment is very high compared to Gävle because of the bags of mixture that are recovered. They amount for approximately 5, 6 % of all garbage.

5 Conclusions

The principal aim of this work was to investigate whether the efforts realized by the city of Barcelona in environmental terms in waste management have succeeded.
As a first conclusion of this study and answering to this main question, it can be stated that a noticeable improvement in terms of environmentally safe management of the wastes has been achieved thanks to the efforts of the city council and of the citizens.
Nevertheless, these efforts are only the beginning of a small improvement in order to be able to meet the objectives and commitments marked by the Agenda 21 local. In this way, it is still necessary to carry out a lot of work, to propose new initiatives and especially a major effort still needs to be done by the inhabitants of Barcelona.

In general, there is a marked trend of an increased generation of wastes. This trend is repeated in many other cities in the whole world, due to the fact that the current socioeconomic context for development is still synonymous of high consumption of material resources. In this way, it is necessary to continue thinking about the increasing generation of urban wastes in order to be able to find practical solutions.

On the other hand, a good civil disposition exists at the moment of separating the selective fractions, and the administration supports efforts that guarantee the incorporation values of the culture in relation with the sustainability to the waste management. This fact allows that the waste generation increasing tendency is accompanied of a very noticeable and significant rise of the wastes fractions gathered selectively. The selective collection has increased a 148 % in Barcelona in only 5 years.

The population has an increasingly active role to what it refers to the separation of the selective fractions of the conventional waste.

A new study in the next few years would be necessary to guarantee that this improvement is well-established and that it is not at a standstill. In this last case, it would be necessary to review and introduce changes in the environmental policy actions.

6 Appendices

6.1 Tables

Table 1: Generation the waste in Barcelona

	2001	2002	2003	2004	2005	2006
POPULATION	1503884	1527190	1582738	1578546	1593075	1605602
TONNES	749948	753460	833455	848771	858868	849332
KG WASTES/INHAB. AND YEAR	498,67	493,36	526,59	537,69	539,13	528,98
KG WASTES/INHAB. AND DAY	1,37	1,35	1,44	1,47	1,48	1,45

Table 2: Segregated collection of glass in Barcelona

	2001	2002	2003	2004	2005	2006
POPULATION	1503884	1527190	1582738	1578546	1593075	1605602
TONNES	11773	13256	20053	21675	23859	25901
KG WASTES/INHAB. AND YEAR	7,83	8,68	12,67	13,73	14,98	16,13

Table 3: Segregated collection of paper and cardboard in Barcelona

	2001	2002	2003	2004	2005	2006
POPULATION	1503884	1527190	1582738	1578546	1593075	1605602
TONNES	31489	32323	57200	65163	79268	85945
KG WASTES/INHAB. AND YEAR	20,94	21,17	36,14	41,28	49,76	53,53

Table 4: Segregated collection of light packing in Barcelona

	2001	2002	2003	2004	2005	2006
POPULATION	1503884	1527190	1582738	1578546	1593075	1605602
TONNES	6016	7490	10642	11696	12661	14086
KG WASTES/INHAB. AND YEAR	4,00	4,90	6,72	7,41	7,95	8,77

Table 5: Segregated collection of organic material in Barcelona

	2001	2002	2003	2004	2005	2006
POPULATION	1503884	1527190	1582738	1578546	1593075	1605602
TONNES	15027	26044	67639	86269	86296	86210
KG WASTES/INHAB. AND YEAR	9,99	17,05	42,74	54,65	54,17	53,69

Table 6: Segregated collection in Barcelona

	2001	2002	2003	2004	2005	2006
POPULATION	1503884	1527190	1582738	1578546	1593075	1605602
TONNES	100713	120881	206077	231812	253839	267240
KG WASTES/INHAB. AND YEAR	66,97	79,15	130,20	146,85	159,34	166,44

Table 7: Generation the waste in Gävle

	2003	2004	2005	2006
POPULATION	154186	154241	154223	154423
TONNES	74545	77556	82130	85779
KG WASTES/INHAB. AND YEAR	483,47	502,82	532,54	555,48
KG WASTES/INHAB. AND DAY	1,32	1,38	1,46	1,52

Table 8: Segregated collection of glass in Gävle

	2001	2002	2003	2004	2005	2006
POPULATION	153631	153312	154186	154241	154223	154423
TONNES	2144	2361	2245	2381	2386	2719
KG WASTES/INHAB. AND YEAR	14,0	15,4	14,6	15,4	15,5	17,6

Table 9: Segregated collection of paper packaging and cardboard in Gävle

	2003	2004	2005	2006
POPULATION	154186	154241	154223	154423
TONNES	6105766	6346863	6431099	8248640
KG WASTES/INHAB. AND YEAR	39,6	41,1	41,7	53,4

Table 10: Segregated collection of newspaper in Gävle

	2003	2004	2005	2006
POPULATION	154186	154241	154223	154423
TONNES	8812	9732	10075	9572
KG WASTES/INHAB. AND YEAR	57,2	63,1	65,3	62,0

Table 11: Segregated collection of metal packaging

	2004	2005	2006
POPULATION	154241	154223	154423
TONNES	524	612	534
KG WASTES/INHAB. AND YEAR	3,4	4,0	3,5

Table 12: Segregated collection of hard plastic packaging in Gävle

	2002	2003	2004	2005	2006
POPULATION	153312	154186	154241	154223	154423
TONNES	368	435	417	525	545
KG WASTES/INHAB. AND YEAR	2,4	2,8	2,7	3,4	3,5

Table 13: Segregated collection of soft plastic packaging in Gävle

	2004	2005	2006
POPULATION	154241	154223	154423
TONNES	460	555	619
KG WASTES/INHAB. AND YEAR	3,0	3,6	4,0

Table 14: Segregated collection of organic material

	2004	2005	2006
POPULATION	154241	154223	154423
TONNES	2763	5609	8308
KG WASTES/INHAB. AND YEAR	17,9	36,4	53,8

Table 15: Segregated collection

	2003	2004	2005	2006
POPULATION	154186	154241	154223	154423
TONNES	39082	40939	48047	54740
KG WASTES/INHAB. AND YEAR	253,5	265,4	311,5	354,5

6.2 Information about Gävle

Gävle, with 92445 inhabitants in 2006, is the largest town in the province of Gästrikland in Sweden.

Gävle is situated by the Baltic Sea near the mouth of the river Dalälven. At 60 degrees north and 17 degrees east, Gävle has the same latitude as Helsinki and the same longitude as Vienna and Cape Town.

Gävle has a similar climate to the rest of central Sweden with an average temperature of −5 °C in January and +17 ° in July. Yearly rainfall is around 600 mm.

It is believed that the name Gävle stems from the word gavel, meaning river banks in old Swedish, by the river Gavleån. The oldest settlement was called Gavle-ägarna in Swedish, which means Gavel-owners. This name was eventually shortened to Gavle, then Gefle, and finally Gävle.

For a long time Gävle consisted solely of small, low, turf or shingle roofed, wooden buildings. Boat-houses lined the banks of Gavleån, Lillån, and Islandsån. Until the 1700s the town was built, as was the practice then, around the three most important buildings; the church, the regional palace, and the town hall.

Over the last 300 years Gävle has been ablaze on three different occasions. After the fire of 1776 the town was transformed to straight streets and rectangular city blocks. The number of stone and brick houses also started to increase. The biggest town fire occurred 1869 when out of a population of around 10,000 approximately 8,000 inhabitants lost their homes, and about 350 farms were destroyed. Almost the whole town north of Gavleån was burnt down. All the buildings south of Gavleån were saved. An area of the old town between the museum and the library has been preserved to this day as a reserve - Gamla Gefle.

After the catastrophe of the fire Gävle developed its characteristic grid plan with large esplanades and green areas. It is now a green town with wide avenues. Stopping the spread of future town fires was the main idea behind this development.

An extensive redevelopment of the central town area was started during the 1950s. Around 1970 Gävle became a large urban district when it was united with the nearby municipalities of Valbo, Hamrånge, Hedesunda, and Hille. New suburbs like Stigslund, Sätra, Andersberg, and Bomhus have grown up around the central town.

6.3 Information about Barcelona

Barcelona is the capital and most populous city of Catalonia and the second largest city in Spain, with a population of 1,605,602 in 2006, while the population of the Metropolitan Area was 3,161,081. It is the central nucleus of the Urban Region of Barcelona, which relies on a population of 4,856,579. It is located on the Mediterranean coast (41°23′N, 2°11′E) between the mouths of the rivers Llobregat and Besòs and is limited to the west by the Serra de Collserola.

Barcelona is located on the Northeast coast of the Iberian Peninsula, facing the Mediterranean Sea, on a plateau approximately 5 km (3 mi) wide limited by the mountain range of Collserola, the Llobregat river to the south-west and the Besòs river to the north[11]. This plateau has 170 km² (66 sq mi)[11], of which 101 km² (38.9 sq mi)[12] are occupied by the city itself. It is 160 km (100 mi) south of the Pyrenees and the Catalonian border with France.

Collserola, part of the coastal mountain range, shelters the city to the north-west. Its highest point, the peak of Tibidabo, 512 m (1,680 ft) high, offers striking views over the city[13] and is topped by the 288.4 m (946.2 ft) Torre de Collserola, a telecommunications tower that is visible from most of the city. Barcelona is peppered with small hills, most of them urbanized and that gave their name to the neighbourhoods built upon them, such as Carmel (267 m), Putxet (181 m) and Rovira (261 m). The escarpment of Montjuïc (173 m), situated to the southeast, overlooks the harbour and is topped by Montjuïc castle, a fortress built in the 17–18th centuries to control the city as a replacement for the Ciutadella. Today, the fortress is a museum and Montjuic is home to several sporting and cultural venues, as well as Barcelona's biggest park and gardens.

The city borders are the municipalities of Santa Coloma de Gramenet and Sant Adrià de Besòs to the north; L'Hospitalet de Llobregat and Esplugues de Llobregat to the south; the Mediterranean Sea to the east; and Montcada i Reixac and Sant Cugat del Vallès to the west.

Barcelona has a Mediterranean climate, with mild, humid winters and warm, dry summers. January and February are the coldest months, averaging temperatures of 10 °C. Snowfalls are so rare that they are remembered as special events. July and August are the hottest months, averaging temperatures of 30 °C. The highest recorded maximum temperature in the city itself is 38.6 °.

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