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Analysis of the Portuguese Municipal Solid Waste Management System

Master Thesis in Environmental Engineering

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ABSTRACT

In the last fifteen years, the Portuguese MSW management system changed significantly, and the legislation and strategic plans have been the main drivers. In this scope, the waste management hierarchy defined in the European policy has been played a main role, since it states that the most desirable option is waste prevention, then reuse and recycling, valorization with recovery energy and the last option should be disposed of in landfills.

In this study is analyzed the evolution of the Portuguese MSW management system from 1995 to 2010. The methodology was based on data collection from several MSW management systems and from the national authority for waste management (Portuguese Environmental Protection Agency – APA). An overview along time about rates of recycling, incineration, composting and landfilling, and some waste management indicators are presented. The greenhouse gas (GHG) and dioxin and furan emissions associated each MWS management option were estimated. The contribution of MWS management to the global GHG emissions represents less than 1%.

Despite all strategic plans, most of MSW in Portugal are sent to landfill. In 2010, 5 million tonnes of MSW were collected and 61% were landfilled, compared to an EU-27 average of 40%. Our analysis showed that the current MSW management system in Portugal is unsustainable when compared with the Europe. In Portugal, until 2020 is expected that landfilling decreases higher than EU average and a slight increasing on incineration.

Keywords: Municipal solid waste, management, greenhouse gas, PCDD/F, carbon footprint.

RESUMO

Nos últimos 15 anos, o sistema de gestão de RSU em Portugal mudou significativamente, muito por força da legislação e dos planos estratégicos. Neste âmbito, a hierarquia para a gestão dos resíduos definida pelas políticas Europeias tem desempenhado um papel fundamental, colocando como mais desejável a prevenção, depois a reutilização e reciclagem, a valorização com recuperação energética e por último a deposição em aterro.

Neste estudo é analisada a evolução do sistema de gestão dos RSU em Portugal desde 1995 a 2010. A metodologia adoptada baseou-se na recolha de dados junto de vários sistemas de gestão dos RSU e da Agência Portuguesa do Ambiente (APA). É produzida uma visão geral ao longo do tempo, sobre as taxas de reciclagem, incineração, compostagem e deposição em aterro, sendo também referidos alguns indicadores de gestão ambiental. São estimadas as emissões de gases de efeito de estufa (GEE) e dioxinas e furanos associadas a cada opção dos sistemas gestão de RSU. A gestão de RSU contribui com menos de 1% para a emissão global de GEE.

Apesar de todos os esforços, a maior parte dos RSU em Portugal são depositados em aterro. Em 2010, dos 5 milhões de toneladas de RSU recolhidas, cerca de 61% foram depositados em aterro, comparando com a média da UE-27 de 40%. O estudo realizado mostrou que o actual sistema de gestão dos RSU é insustentável quando comparado com a média Europeia. Até 2020 prevê-se que em Portugal ocorra uma diminuição na deposição em aterro superior à da média Europeia, e um ligeiro aumento da incineração.

Palavras-chave: Resíduos sólidos urbanos, gestão, gás de efeito de estufa, PCDD/F, pegada de carbono.

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ACRONYMS

APA - Agência Portuguesa do Ambiente [Portuguese Environmental Agency]

BAT - Best available technology

BOD_5 – Biochemical oxygen demand in 5 days

BOD_5/COD - Biodegradability rate

BMW - Biodegradable municipal waste

CF - Carbon footprint

CDR - Construction and demolition residues

COD - Chemical oxygen demand

DOC - Degradable organic carbon

DDOC - Dissimilable degradable organic carbon

ECTRU - Estação de confinamento técnico de resíduos urbanos [Technical confinement station for urban wastes]

EGF - Empresa Geral do Fomento

ENRRUBDA - Estratégica nacional para o desvio de resíduos urbanos biodegradáveis de aterro [National strategy for diverting biodegradable municipal wastes to landfill]

ERSAR - Entidade Reguladora dos Serviços de águas e resíduos [Regulatory Authority of water and waste services]

GHG - Greenhouse gases

GWP - Global warming potential

INR - Instituto nacional de resíduos [National institute of wastes]

Inhab. - Inhabitant

IPCC - Intergovernmental plane on climate change

MBT - Mechanical biological treatment

MSW - Municipal solid waste

Mt - Mega tonnes

PCDD - Polychlorinated dibenzo-*p*-dioxins

PCDF - Polychlorinated dibenzofurans

PEGRA - Plano estratégico de gestão dos resíduos dos Açores [Azores strategic plan for MSW management]

PERSU - Plano estratégico dos resíduos sólidos urbanos [Portuguese strategic plan for MSW management]

PERRAM - Plano estratégico dos resíduos da região autónoma da Madeira [Madeira strategic plan for MSW management]

PNAC - Plano nacional das alterações climáticas [Nacional plan of climate change]

PNGR - Plano nacional de gestão de resíduos [National plan of waste management]

POP - Persistent organic pollutant

RDF - Refuse derived fuel

SIRAPA - Sistema integrado de resíduos da Agência Portuguesa do Ambiente [Integrated waste system of Portuguese Environmental Agency]

SGRSU - Sistemas de gestão de resíduos sólidos urbanos [Urban solid wastes management system]

SPV - Sociedade Ponto Verde [Green dot system]

TEQ -Toxicity equivalent

TSS - Total suspended solids

TOC - Total organic carbon

WMS - Waste management system

1. INTRODUCTION

This chapter presents an introduction to the problems intended to be treated throughout the study. The motivations of this research, as well as the objectives defined and the methodology are indicated. Finally the structure of the thesis is explained.

1.1. Thesis goal and motivation

Environmental management of resources is a vital step towards preservation of available nature reserves on earth and the survival of living beings (Kollikkathara *et al.*, 2009). In this scope, it is fundamental to note that *'Waste is simply resources out of place'*.

Population growing, technological development, and the unsustainable consumption habits, has led to high consumption of resources in relation to the existing capacity. Consequently, it has been observed an increasing production of wastes. In this context, there is a need of develop integrated management of municipal solid waste (MSW) that are nowadays produced and generated exponentially.

Until the 1970's, even in European Union, there is no legislation related with waste issues. Waste management is now addressed in all developed countries that have implemented and developed environmental policies. Only in the last two to three decades, MSW became a major problem and currently one of the main public concerns. So, in the 21st century, a sustainable management of MSW is essential, to planning all the involved (Pássaro, 2003; Magrinho *et al*., 2006; Pires *et al.,* 2011).

The implementation of the first strategic plan for municipal solid waste (PERSU I) marked a turning point in the field of MSW management in Portugal. This document defined the application of a hierarchy of principles based on the strategic foundations of the EU (MAOTDR, 2007).

MSW management activities contribute to the generation of greenhouse gas (GHG) and consequently to the climate change problem. The activity related to the landfilling has a large impact on the formation of these gases. Other environmental problem associated with the MSW management system is the potential generation of dioxins and furans, associated mostly with incomplete combustion of wastes (Smith *et. al.*, 2001; UNEP Chemicals, 2005).

Despite some strategic plans of MSW management have been adopted, several studies showed the lack of data and inconsistencies of some results in what respect MSW management (Magrinho *et al.,* 2006; Koufodimos and Samaras, 2002). Thus, there is real need to collect data from all existing sources, extending the analysis to wider timelines. In this scope, our study can provide a valuable contribution.

In fact, the timeframe under review was from 1995 to 2010, and includes both strategic plan (PERSU I and PERSU II). To obtain data necessary for analysis, the main sources were APA, INE, EEA, EUROSTAT and OECD. The main objective is to assess the influence of MSW strategic plans and legislation on the wastes management system evolution and infrastructures facilities. The second goal is to quantify GHG emissions and dioxins and furans releases emitted in the several technologies associated with MSW management system.

1.2. Thesis Structure

This study is divided in 5 Chapters:

- chapter 1: is an introduction about the thesis goal and motivation;
- chapter 2: is an introduction about MSW management system and include treatments options description and indicators assessed. An overview about environmental impacts associated with MSW management, are also indicated;
- chapter 3: provides a literature survey of the theme under analysis;
- chapter 4: presents the results obtained in our study about MSW management indicators, dioxins and furans and GHG emissions results associated with MSW management;
- chapter 5: summarizes the conclusions of this study and indicates future work.

2. MUNICIPAL SOLID WASTE MANAGEMENT – FRAMEWORK

The purpose of this chapter is to provide a framework of the concept of waste management, describing all phases regarding the system and wastes treatment methods and technologies used. An introduction of Portuguese wastes management system (WMS) and indicators used are presented. The environment impacts associated with WMS and related legislation are explained.

In 1975, upon the establishment of the Directive 75/442/EEC of the European Economic Community, the first definition of waste was created. Since then, the definition of waste has undergone significant changes. With the publication of the Directive 2008/98/EC of the European Community (now in force), the concept of waste has been extended to include by-product and end-of-waste contributing to a comprehensive waste management for raising awareness of waste management (PNGR, 2011). The national definition of waste is set out in Decree law nº 178/2006 of September 5. According to this, "*waste is any substance or object which the holder discards or intends to discard*".

Regarding the origin, waste may be classified as medical, industrial, agricultural and municipal solid waste. Only the latter one will be investigated in this study. Within the universe of municipal solid waste, the waste from households and from trade and services (e.g. shops, offices and hotels) are considered the main sources. In the Portuguese legislation referred above municipal solid waste (MSW) is defined as "*waste from households and other waste which by its nature or composition is similar to waste from households*" (Decree-Law nº 178/2006).

Within the MSW, the waste streams addressed are: glass, paper and cardboard, metal and plastic.

2.1. Waste Management and treatment options

The waste management plan includes the following operations: collection, transport, storage, treatment, recovery and disposal. Directive 2008/98/EC forces member states to adopt sustainable treatment technologies environmental friendly. Thus, the hierarchy of waste management (Fig. 2.1) recommended to all member states is: prevention and reduction, reuse, recycling, organic and energy recovery and disposal of. The main MSW treatments are briefly described in Tab. 2.1.

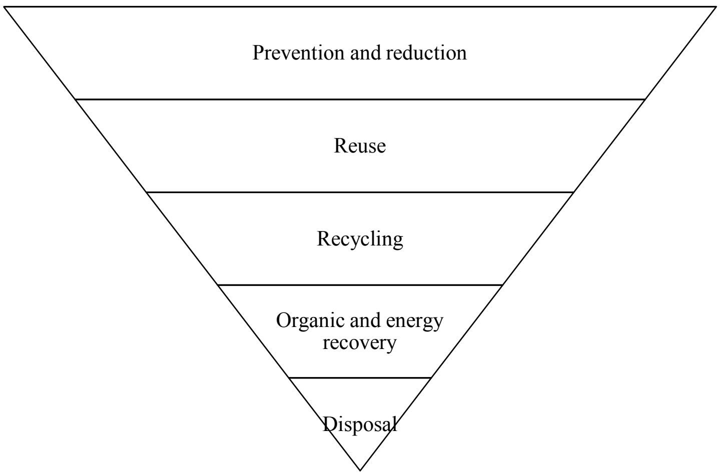


Fig. 2.1 - Waste management hierarchy (adopted from Directive 2008/98/EC).

Tab. 2.1 - Waste treatment options (adapted by Smith *et al.*, 2001).

Treatment options	Process Description
Dumping	Uncontrolled deposition of waste on land.
Landfilling	It encompasses the management of waste disposal on land, with or without pre-treatment. Landfill gas and leachate are produced.
Incineration	Burning of waste at high temperatures, with or without pre-treatment. Energy recovery may occur.
Recycling	Several components of the waste stream are reused and recover.
Composting	Decomposition of organic wastes by microorganisms under oxygen atmosphere and producing a compost used as soil conditioner.
Anaerobic digestion	Similar to composting but the process occurs without oxygen, converting biodegradable wastes in biogas (CO_2 and CH_4) which can be used as an alternative fuel.
Mechanical Biologic Treatment (MBT)	It is a pre-treatment coupling mechanical and biological treatments. The aim is to separate biodegradable waste and reducing the amount of waste to landfill, by sorting recyclable waste.

A general overview of MSW management options is shown in Fig. 2.2, based on the Smith *et al*. (2001) study, where the main options are landfill pre-treatment, landfill of untreated wastes and recycling. Mobilization of waste includes the steps of segregation, collection, transport and sorting. Anaerobic digestion and composting are described as biologic recycling. Mechanical recycling is related to materials such as glass, paper, plastic and metal. Non recycled waste may undergo treatment before landfilling. Thermal treatment (incineration) and MBT allow reducing the amount of waste to landfill.

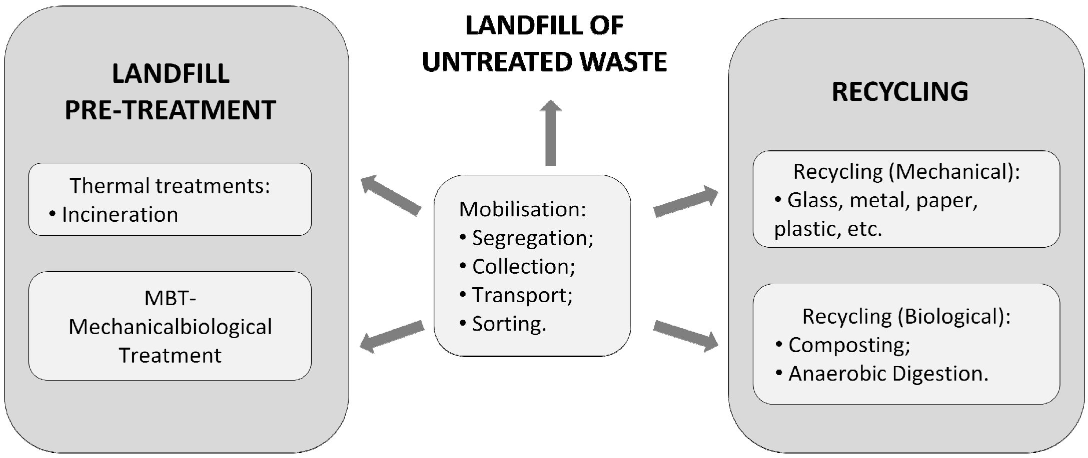


Fig. 2.2 - Waste management options (based on Smith *et al.*, 2001).

A scheme of the Portuguese MSW management organization is described in Fig. 2.3 which involves collection, storage, treatment and disposal. MSW collection includes selected wastes and unselected wastes. The unselected wastes are under the responsibility of each municipality, though the selected wastes are under the responsibility of the municipalities, the MSW management system (SGRSU in portuguese) and private companies (Magrinho *et al.,* 2006). The ecocentres and ecopoints are devoted to selected wastes. Ecocentres are used wastes with large volume. In addition to the materials referred above as part of mechanical recycling, there are others specific flux of wastes (used oils, batteries, electrical and electronic wastes, construction and demolition residues (CDR), end-of-life vehicles and used cooking oil. Transfer station provides the facilities required for unselected wastes when landfill or MBT are far away. So, unselected collection can be understood as the sum of landfilling wastes with energetic and organic refuses. The selected collection includes ecopoints and door-to-door collection with ecocentres and biodegradable municipal waste collection (APA, 2010a). MBT plants are designed to process mixed household wastes as well as commercial and industrial wastes. The MBT allows to recycle materials such paper, metal, plastic and glass. However, it can produce refuse derived fuel (RDF) or stabilize the biodegradable materials by composting or anaerobic digestion. The RDF can be further used as alternative fuel in cement kilns or incinerated to produce energy. The ash formed during incineration contains mostly inorganic constituents of the wastes, that is often landfilled.

Biodegradable wastes can be converted into compost, carbon dioxide and water under aerobic process. Composting is common technology for organic recovery of the wastes into soil conditioner. The remaining non biodegradable wastes are recycled in order to recover materials to produce new products.

The other wastes from unselected collection as well as waste coming from MBT, incineration plants, composting and recycling refuses are disposed of in landfills. Landfilling is the last treatment to be adopted, because it causes severe environmental impacts not only at the level of gases released into the atmosphere contributing to global warming, but also in terms of leachates produced. To minimize the environment impact, the biogas generated by anaerobic reactions can be used as fuel to produce electricity and heat. Biogas comprises mainly methane (CH_4) and carbon dioxide (CO_2) and may have small amounts of hydrogen sulphide (H_2S) and moisture. Biogas is a renewable fuel and can be cleaned and upgrade to natural gas standards.

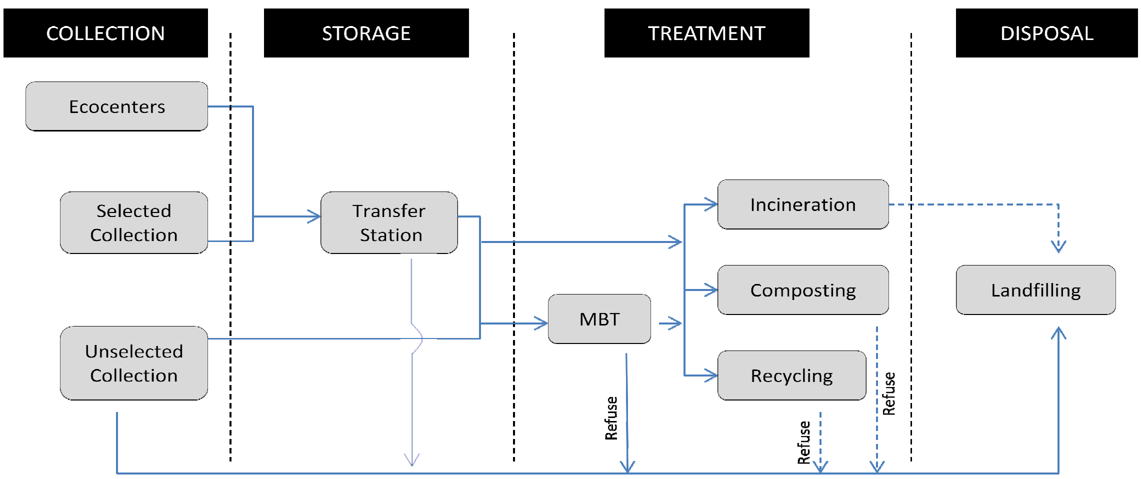


Fig. 2.3 - Portuguese Municipal Solid waste management scheme (adapted from MAOTDR, 2007).

2.2. Indicators of waste management

The indicators of waste management allow to evaluate the status and progress of a specific flux waste or of total amount. According to APA (2003) there are several factors related to the evolution of waste production that can be used in this scope:

- the demographic evolution;
- the evolution of economic activity, i.e., gross national income, defined in Portuguese as the “produto interno bruto” (PIB);
- the evolution of GHG emissions;
- the increasing consumption and primary energy use.

The PIB is used to monitor the country's economic development and is an indirect indicator of the overall social development. Therefore, it can be used to evaluate development of MSW production (APA, 2011a). Sometimes the waste production increases more than PIB as result of the economic crisis (APA, 2010b). However, in general, an agreement is usually observed between MSW production and this socio economic indicator.

So, the objectives and results regarding management can be evaluated through the use of social, economic or environmental indicators (Desmond, 2006). In our study, only environmental indicators were used, such as: waste per capita [kg/inhab.year], total wastes produced [tonne/year], waste treatment ratio [%], infrastructures [number] and ratio of ecopoints [inhab./ ecopoint]. Some of these indicators are used in Chapter 4 to evaluate the MSW management in Portugal from 1995 to 2010.

2.3. Environmental impact for waste treatment options

The activities associated with MSW management and treatments have a noticeable impact at several levels. The main positive and negative impacts associated with the different treatment options are summarized in Tab. 2.2. In general all waste treatments have noise and odor impacts.

Despite the environmental impact mentioned in Tab. 2.2 only the ones greenhouse gases and dioxins releases are assessed in this study. Although landfilling is the last option treatment in the waste management hierarchy it is still widely used (Magrinho *et al*., 2006). The main reasons for that are: the low cost of landfill installations and operation, the large area available to install landfills and the small dimension of the MSW management systems (SGRSU).

Tab. 2.2 - Environmental impacts associated to the waste management treatment options (Smith, *et al* 2001).

Treatment options	Main environmental impacts
Landfilling	CH_4 emissions from biodegradable wastes (global warming contribution); Retention of carbon compounds in the landfill; Water pollution through leachates production; CO_2 and other compounds emissions.
Incineration	Emissions of dioxins, fine particles and NOx, SO_2 and HCl; CO2 emissions from fossil-derived fuels (e.g. plastic) and NO_2 (global warming contribution); Replacement of fossil fuels by energy recovered.
Recycling	Lower emissions of greenhouse gases and other pollutants; Less virgin feedstock extraction resulting in energy savings and fewer impacts; CO2 emissions.
Composting	CH_4 emissions avoided; The compost replaces chemical fertilizers, resulting in soil improvement; Potential for carbon sequestration due to the presence of organic matter in soil; CO_2 emissions.
Anaerobic Digestion	CO_2 avoided emissions due to replace fossil fuels and energy recovered. Sludge production.
MBT	Reuse of materials for recycling and energy recovery; Reduction of methane and leachate production; Landfills are needed for disposal of unrecovered waste.

2.3.1. Leachates from landfill sites

In spite of the total eradication of the dump sites in Portugal, the main objective of PERSU was a gradual increase of the number of sanitary landfills. However, even in this case, the leachate remains a problem and it is responsibility of each municipality to control its discharge in water courses according to legislation thresholds.

Thus, in order to prevent and control contamination of ground and surface water and the soil contamination, it is necessary to implement appropriate treatments for the leachate produced in landfills. So, it is necessary to take into account several factors in order to choose the best treatment, such as waste composition, rainfall, and type of landfill management operation. On the other hand, also situations of breakdown in the functioning and extreme rainfall conditions must be considered in order to ensure that treatment options are effective and efficient as a whole (IRAR, 2008).

According Levy and Cabeças (2006) in a landfill the main inputs waste and rainwater, and biogas (CH_4 and CO_2) and leachate are main outputs. Leachates is formed principally due to rainfall percolating through waste mass deposited in the landfill dragging dissolved and suspended materials. Landfill biogas production is dependent on the action of anaerobic microorganisms that in the absence of oxygen and of specific compounds are available, produce CO_2 and CH_4.

According to IRAR (2008) the main functional parameters of landfill leachates are: chemical oxygen demand (COD), biochemical oxygen demand in 5 days (BOD_5), biodegradability ratio BOD_5/COD, total suspended solids (TSS), total nitrogen and total organic carbon (TOC).

COD provides an estimation of the amount of organic matter, BOD_5 correspond to the quantity of the biodegradable compounds present in the leachate and TSS values are associated with the suspended matter present in leachates (Lopes, 2011). Landfill is therefore a technology with some negative environmental impacts (mainly leachate and biogas) which did not stop after its closure. Thus it is important to monitor these sites over the years. Tab. 2.3 shows typical composition of leachates from MSW landfills according to the literature (Tchobanoglous, 1993). It is important to note that the leachate is produced in larger quantities and high concentrations during the filling of the cells.

Tab. 2.3 - Typical values of the composition of young and old landfill leachates (Tchobanoglous *et al.*, 1993).

Parameters	Young Landfill range (<2 years)	Former landfill range (> 10 years)
pH	4,5 - 7,5	6,6 - 7,5
(mg/l)		
BOD_5	2000 - 30000	100 - 200
COD	3000 - 60000	100 - 500
TOC	1500- 20000	80 - 160
TSS	200 - 2000	100 - 400
Organic nitrogen	10 - 800	80 - 120
Ammoniacal nitrogen	10 - 800	20 - 40
Nitrates	Mai-40	05-Out
Total phosphorus	1 - 100	05-Out
Alkalinity as CaCO3	1000 - 10000	200 - 1000
Total hardness as CaCO3	300 - 10000	200 - 500
Calcium	200 - 3000	100 - 400
Magnesium	50 - 1500	50 - 200
Potassium	200 - 1000	50 - 400
Sodium	200 - 2500	100 - 200
Chlorides	200 - 3000	100 - 400
Sulphates	50 - 1000	20 - 50
Total Iron	50 - 1200	20 - 200

2.3.2. Polychlorinated dibenzo-*p*-dioxins and dibenzofurans

Polychlorinated dibenzo-p-dioxins (PCDD) and plychlorinated dibenzofurans (PCDF) are major Persistent Organic Pollutants (POP'S) on the list of the 12 pollutants under the Stockholm Convention. The unintentionally production of PCDD/F is associated with the manufacturing of pesticides and other chlorinated substances, as well as with the incomplete combustion of MSW, industrial and hazardous wastes (Stockholm Convention, 2011).

According to the Stockholm Convention, 2011, the main environmental problems of PCDD/F are:

- remain intact over a long period of time;
- great capacity to disperse in the environment through water, air and soil;
- accumulate in the tissues of living beings, especially in the fat ones;
- be toxic to animals and living beings.

In 2005, a methodology for estimating emissions of PCDD/F called 'Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases' was developed, by UNEP Chemicals. The aim of this standardized Toolkit was to provide an inventory of the emissions of dioxins and furans associated with several existing categories, for all countries. So, this issue will be addressed later in our associated with the various stages of MSW treatments, with the aim of calculating PCDD/F releases (g TEQ/year) for the period under analysis (1995-2010).

2.3.3. Greenhouse Gases

According to the Intergovernmental Plane on Climate Change (IPCC), the greenhouse gases (GHG) that most contribute to global warming are: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and hydrofluorocarbons (HFC). The emission of these gases may occur in all stages of MSW management. There are several factors that determine the total amount of GHG emitted over the MSW management system, namely: the amount of waste produced, the waste composition (mainly the carbon content) and the technologies used to handling and disposal (Friedrich and Trois, 2011).

To estimate the quantities of emitted GHG, the carbon footprint (CF) of waste management was calculated. The CF is an indicator of environmental impact which can be estimated by the GHG emissions and the calculation of life cycle energy consumption associated with a particular activity. The implementation of this methodology is a plus, as it is useful in the implementation and reinforcement of national decisions in the management of MSW (Cifrian *et al.*, 2011).

The GHG emissions associated with MSW management are expressed in CO_2 equivalents (CO_2 eq.) taking into account the global warming potential (GWP) of each gas. GWP is a factor that allows the concentrations of GHG to be expressed in terms of the amount of CO2 that would have the same global warming impact. The GWP of CO_2 from fossil sources is assigned a value of 1 and corresponds to 3215 Mt emissions of CO_2. CH_4 and N_2O are, respectively, 21 and 310 times more potent in global warming terms than the same mass of CO_2 (over a 100-year horizon) (Smith *et al.*, 2001). Using as support the study of Smith *et al.* (2001) whose objective was to determine emission factors associated with various treatment options for MSW, through a balance of direct and avoided emissions, the CF (kg CO_2 eq/tonnes waste) in the various stages of treatment of MSW management over the period 1995 - 2010 is estimated in Chapter 4.

2.4. Portuguese waste management system

2.4.1. Roles and responsibilities

A scheme of the Portuguese waste management system and responsibilities is shown in Fig. 2.4. In Portugal the authority for waste management activities is the Portuguese Environmental Protection Agency (APA) which aggregates "Instituto Nacional de Resíduos" (INR) and "Instituto do Ambiente" according to the Regulamentar Decree nº 53/2007. The "Sociedade Ponto Verde" (SPV) is responsible for management of packaging waste and establishes contracts with collecting consortia and recycling companies. The "Ministério da Agricultura, do Mar, do Ambiente e do Ordenamento do Território" (MAMAOT) is the governamental regulatory body which is responsible for promoting and adopting the principles to protect the environment in terms of a sustainable environment, creating legislation and European Directives transposition. The MSW is managed under the urban solid waste management system (SGRSU) that includes municipalities. Indeed, in most cases, municipalities are responsible for the collection of selected and unselected waste. The participation of citizens, trade and services, which are the major waste producers, is essential to achieve targets. Private and public companies coorporate in collection and management waste under the framework of the legislation and monitoring of APA.

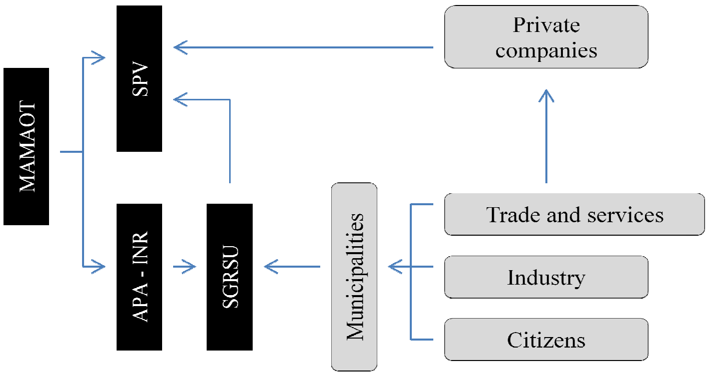


Fig. 2.4 - Portuguese waste management and responsibility scheme (adapted from Magrinho *et al.*, 2006).

MAMAOT-Ministério da Agricultura, do Mar, do Ambiente e do Ordenamento do Território; SPV-Sociedade Ponto Verde; APA-Agência Portuguesa do Ambiente; INR-Instituto Nacional de Resíduos; SGRSU- Sistemas de Gestão de Resíduos Sólidos Urbanos.

The collection, transport and management of MSW in Portugal is mainly a responsability of municipal and intermunicipal systems emerged as a reply to the objectives proposed by the first strategic plan of MSW in Portugal (PERSU I). In this scope, municipalities use public funding to creating common facilities for management and treatment of wastes (Magrinho *et al.*, 2006). Basically, these companies build logistic equipment and infrastructure facilities to solve all operations related to MSW management in order to facilitate the implementation of project targets. The systems are divided into multimunicipal and intermunicipal systems. The first one is managed by public enterprises, such as the Empresa Geral do Fomento (EGF) and the second one involves associations governed by various municipalities distributed in the country according areas and population. Before SGRSU is in force, the collection of waste was carried out by local authorities (APA, 2011b).

2.4.2. Strategic plans

National legislation currently in force concerning MSW management options is the Decree law nº 73/2011, of June 17 which makes the third change to Decree law nº 178/2006, of September 5 transposes Directive 2008/98/EC of the Parliament and the council.

The main objectives outlined by this law are:

- strengthening the prevention of waste production by stimulating the reuse, recycling and consequently the waste recovery;
- encourage the collection of organic waste;
- to clarify and to review the concepts related with the management of MSW;
- to approve prevention programs with goals at the level of reuse, recycling and recovery until 2020;
- to outline criteria for removing the status of certain waste materials;
- to introduce the concept of extended producer responsibility.

The first municipal waste strategic plan in mainland Portugal issued in 1997 and known as PERSU I was set up following the 75/442/EEC European Directive, of 15 July 1975, Waste Framework Directive. The PERSU I promoted companies dedicated to waste management, such “Sociedade Ponto Verde” (SPV) which is devoted to packaging waste management. The main objectives of European Directive 75/442/EEC were adopted as the prime objectives of PERSU I as follows:

- the total eradication of open dumps in Portugal;
- the construction of multimunicipal and intermunicipal systems for MSW management;
- the construction of waste treatment infrastructure (recovery and disposal);
- the implementation of selective collection with ecopoints and ecocentres installation.

In general, all these objectives are intended to create a sustainable development for MSW management for the period from 1997 to 2006. In 1995 prevention was placed at the top of the management pyramid of treatment. The non-existence of standards for waste management and the difficulty of predicting long-term goals, mean that the plan horizon was divided in three periods, 2000, 2005 and 2010. From the available records of waste, an increase around 3% per year was predicted (MA, 1999).

Fig. 2.5 shows the waste treatment options in 1995, which ones were used to predicted the situation in 2000 and 2005. The ECTRU represents the intermediate stations for MSW. It is impostant to note that PERSU I predicted decrease of 2.5% of total MSW (around 100×10^3 tonnes) in 2000 and about 5% of total MSW reduction (around 225×10^3 tonnes) in 2005. Difficulties to predict accurately long-term goals, made 2010 predictions unfeasible.

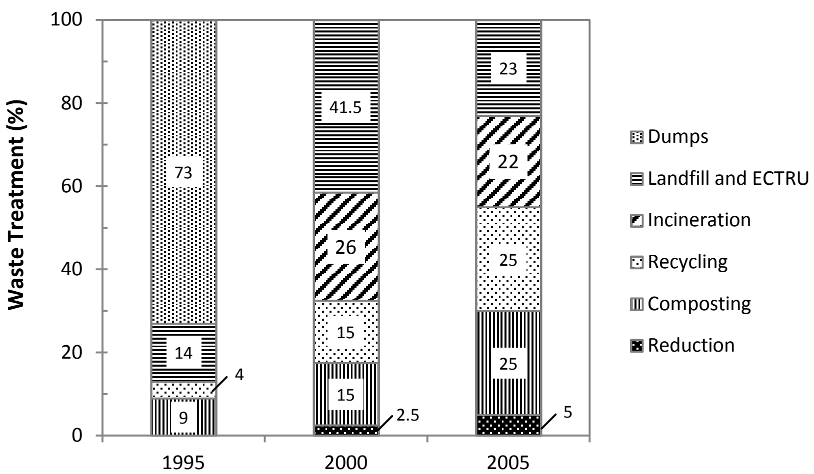


Fig. 2.5- Horizon plan goals of PERSU I (adopted by MA, 1999).

Fig. 2.6 demonstrates that the situation in 2005 was far from the targets and thus the strategic plan and the objectives were revised. Only waste incineration results were close to predict ones.

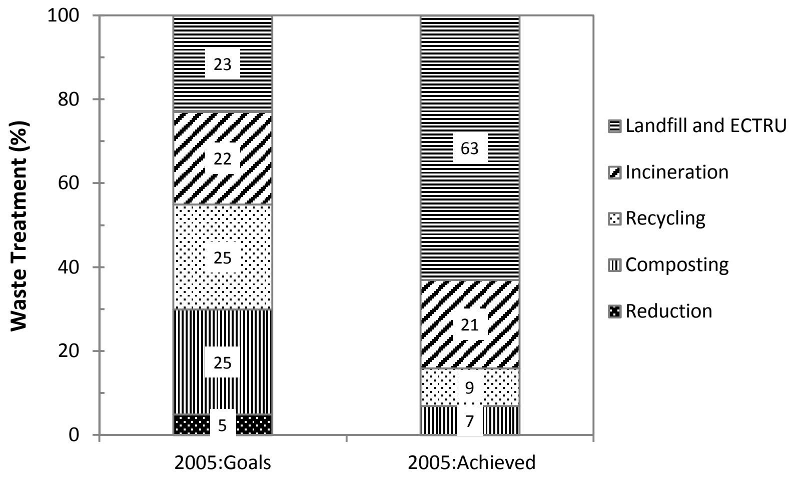


Fig. 2.6 - Comparison of waste treatment in 2005: projected vs achieved (MAOTDR, 2007).

Despite the high percentage of waste deposited in landfill when compared with others treatments, the PERSU I had a positive balance. In fact, all dumps were closed, multimunicipal and intermunicipal systems for MSW management were implemented, recycling and recovery infrastructure were built and selective collection was implemented (MAOTDR, 2007). However, the performance results were below predictions, namely the landfilled amount was almost three times higher than the predictions.

By those reasons and due to new directives (Directive 2006/12/EC, April l5 and Directive 2004/12/EC, February 11) issued, the PERSU I was revised and led to PERSU II in 2007 (MAOTDR, 2007). This second strategic plan (PERSU II) established targets for the period 2007-2016 applied only to mainland Portugal. The main goals of the new strategic plan are:

- the review of PERSU I goals;
- to deviate biodegradable MSW from landfill to composting and incineration coupled with MBT;
- the commitment to reduce greenhouse gas emissions (Kyoto protocol);
- the development of recovery technologies, investing in units to produce refuse derived fuel (RDF).

Fig. 2.7 shows the waste treatment plan established for the period 2005 – 2016, which include 2005 as baseline. The moderate scenario goals for the horizon plan of 2009, 2011 and 2016 were adopted. The biodegradable wastes considered are produced in MBT units and MBT are these fractions that are sold and recycled. This strategic plan is now in force but constant reviews are carried out by reason of progress reports.

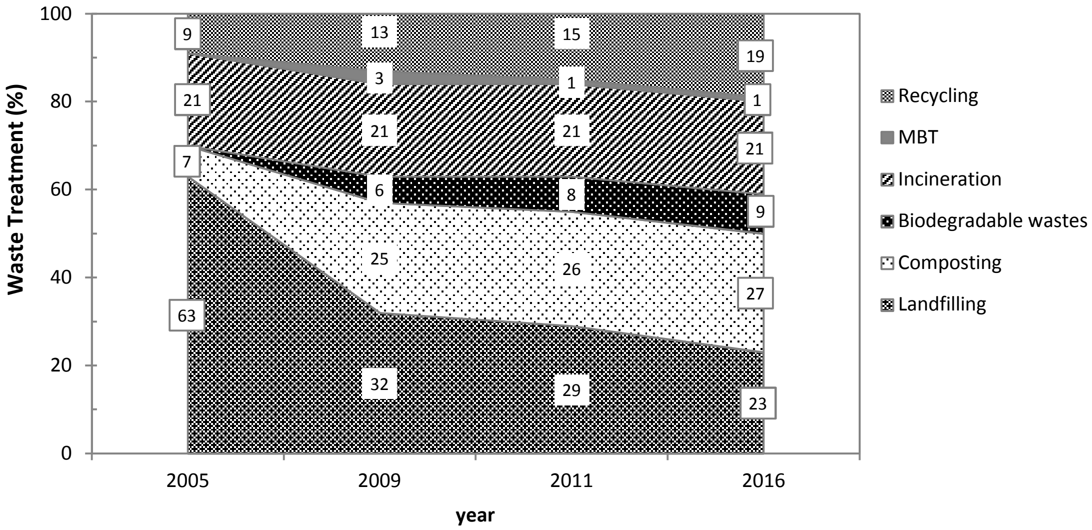


Fig. 2.7 - Projected waste treatment according PERSU II: period 2005 – 2016 (adopted by MAOTDR, 2007).

The approval of Decree-Law nº 178/2006 of September 5 was a decisive step to the municipal waste management, since established the national plan on waste management, (PNGR), which entered into force in 2011, and will be in force until 2020. The aim is to build an integrated network and suitable facilities for valorization and disposal of all type of wastes applying the best available technologies and maintaining sustainable costs (PNGR, 2011). PNGR requires:

- the description of the collection systems and major waste facilities for valorization and disposal, and;
- an assessment of the needs for new systems of collection, closure of existing waste facilities and additional infrastructures.

As mentioned before, PERSU II is only applied to mainland Portugal. For Madeira and Azores archipelagos, PERRAM e PEGRA strategic plans respectively are applied.

2.4.3. Urban solid waste management systems and infrastructures

Since 1997, when the PERSU I was issued the numbers of SGRSU is decreasing as shown in Fig. 2.8. The progressive merge of systems contributed to this reduction, which was imposed by the goals of PERSU II that favored the aggregation of systems to maximize waste recovery using the existing infrastructures (APA, 2011b). Nowadays there are 23 SGRSU in mainland Portugal (Fig. 2.9), being 12 multimunicipal and 11 intermunicipal. Tab. 2.4 describes in detail the existing SGRSU in 2010 and their characteristics, including their infrastructures. Thus, in 2010 there are in mainland Portugal 34 landfills, 29 sorting centres, 81 transfer centres, 190 ecocentres, 37971 ecopoints, 2 energy recovery centres, 11 organic recovery facilities and 7 MBT.

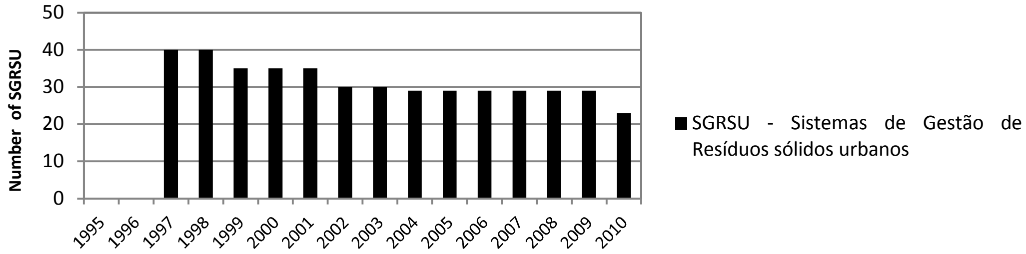


Fig. 2.8 - SGRSU number evolution since 1995 until 2010 (sources: MAOTDR, 2007, Magrinho, 2006, APA, 2011b).

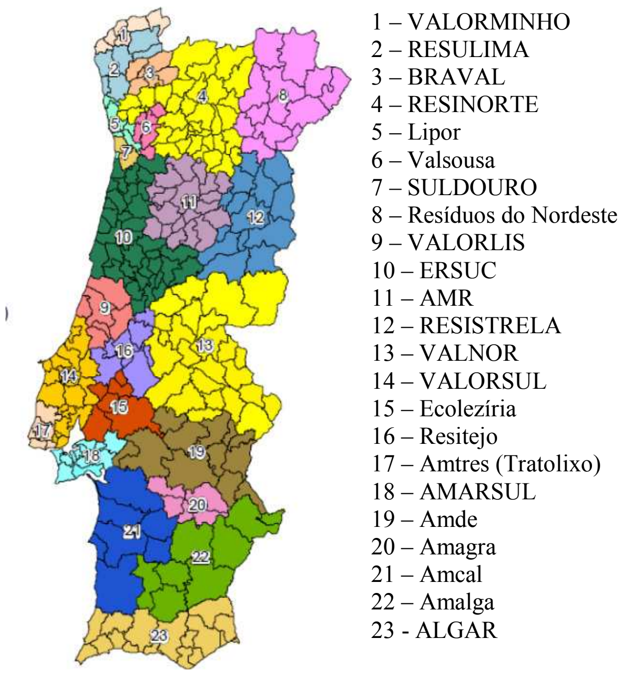


Fig. 2.9 - Existing SGRSU in mainland Portugal in 2011 (source: APA, 2011b).

Tab. 2.4 - SGRSU and infrastructure existing in mainland Portugal in 2010 (source: APA, 2010c).

System	Area [km^2]	Inhab [Censos 2011]	Municipalities	Infrastructure							
				Landfill	Sorting centres	Transfer centres	Ecocentre	Ecopoints	Energy recovery centre	Organic recovery centre	MBT
VALORMINHO	944	77704	6	1	1	1	2	470	-	-	-
RESULIMA	1778	322096	6	1	1	1	2	912	-	-	-
BRAVAL	1121	290508	6	1	1	1	2	1131	-	-	-
RESINORTE	8090	956763	35	5	4	8	15	3282	-	1	-
LIPOR	648	984047	8	1	1	-	21	3565	1	1	-
VALSOUSA	764	337609	6	2	3	2	8	756	-	-	-
SULDOURO	384	441485	2	1	1	-	4	1489	-	1	-
RESIDUOS DO NORDESTE	6997	143777	13	1	-	4	14	580	-	-	1
VALORLIS	2159	307265	6	1	1	3	4	984	-	-	1
ERSUC	6699	956808	36	3	2	6	7	3557	-	-	1
AMR	4660	349720	19	1	1	3	19	1334	-	1	1
REISISTRELA	6160	202761	14	1	1	8	14	625	-	1	-
VALNOR	11980	272195	25	2	1	7	13	1346	-	1	-
VALORSUL	3345	1610786	19	2	2	6	8	5537	1	1	-
ECOLEZIRIA	2941	127058	7	1	-	2	4	366	-	-	-
RESITEJO	2460	209587	10	1	1	3	9	1201	-	1	-
AMTRES (Tratolixo)	753	831178	4	1	-	3	2	4406	-	-	1
AMARSUL	1520	778028	9	2	2	1	7	2378	-	1	-
AMDE	6400	155268	12	1	1	4	7	652	-	-	1
AMAGRA	6408	115417	7	1	1	4	7	505	-	-	-
AMCAL	1749	25506	5	1	1	2	4	111	-	-	1
AMALGA	6650	95763	8	1	1	4	5	380	-	-	-
ALGAR	4988	450484	16	2	2	8	12	2404	-	2	-
TOTAL	89598	**10041813**	279	34	29	81	190	37971	2	11	7

2.5. EU strategic plans and instruments for diverting biodegradable municipal waste away from landfill

Biodegradable municipal waste (BMW) is set out by Landfills Directive (Directive 1999/31/EC of 20 April 1995) as '*any waste that is capable of undergoing anaerobic or aerobic decomposition such as food and garden waste and paper',* i.e., paper/cardboard, food wastes, garden wastes, textiles and wood. With this Directive, all Member states are obligated to implement national strategies to divert the amount of BMW landfilling. The aims were to improve resource use and minimize environmental impacts. The goals of diverting are:

- 35% reduction of the amount of BMW generated in 1995 by 2006;
- 50% reduction of the amount of BMW generated in 1995 by 2009;
- 75% reduction of the amount of BMW generated in 1995 by 2016.

Fig. 2.10 shows all BMW fluxes in four phases that require analysis, such as production, storage, treatment and final destination.

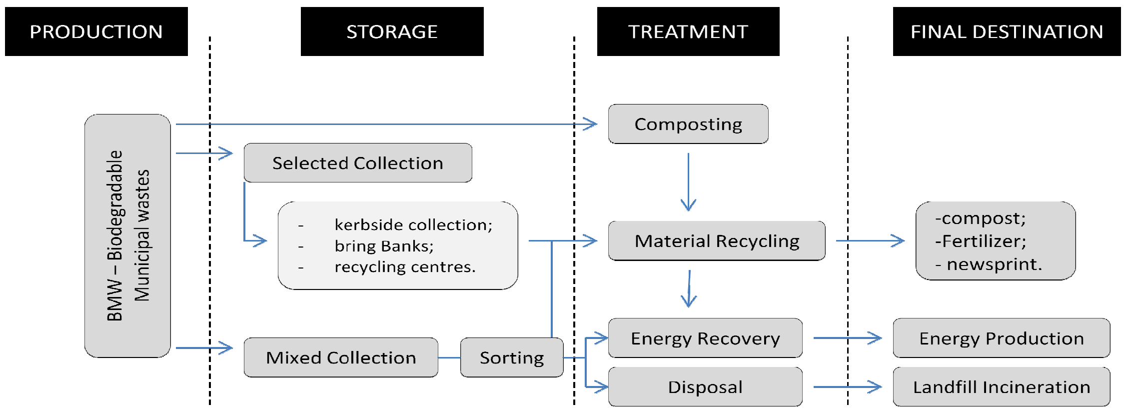


Fig. 2.10 - Flow for biodegradable municipal waste (adapted by Crowe *et al.*, 2002).

The production of BMW is the most difficult phase for a successful implementation of prevention and minimization measures (as designated at the top of the waste hierarchy pyramid). The storage involves collection and transfer wastes processes. The way that wastes are collected has a large effect in the available treatment operation, thus, this step is decisive for the BMW landfill diverting. Here, wastes can be collected for three different ways: direct from households (kerbside collection), use of collection receptacle in proximity to households (bring banks) and delivery direct to waste facilities (recycling centers). After that, BMW can be recovery with several treatments options available, which, in turn, are related with the respective collection types. The last option is the final deposition of BMW to guarantee that all goals were ensured to divert, as much as possible, BMW for landfill (Crowe *et al.*, 2002).

In order to put into practice standards that minimize the deposition of BMW in landfills, national strategies must address the waste prevention and minimization and its member states should implement measures to encourage their practices. So, Crowe *et al*. (2002) suggests the measures summarized in Tab. 2.5:

Tab. 2.5 - Measures for BMW landfill diverting (adapted from Crowe *et al.*, 2002).

Phase	Process
BMW Production	Consumer awareness, public education and fiscal instruments; Separation at source; Home Composting; Producer responsability iniciatives and instruments.
BMW Collection	Legal obligations requiring separate collection; use of presentation by-laws and fiscal instruments; Sustained public education campaings.
BMW Treatment	Taxes of financial incentive to divert waste from landfill.
BMW Disposal	Maximizing the potential for reuse of the materials contained in the flow.

Crowe *et al.,* (2002) also present examples of success cases such as Denmark, the Netherlands and Flanders (Belgium) that diverts large quantities of BMW from landfill and incineration and has high rates of recovered materials, thereby also reducing landfilling. This is due to the implementation of legal requirements for the BMW collection. Despite all these positive comments, there are also risks associated with illegal disposal of biodegradable waste to avoid paying taxes. So, there must be an adequate and functional network of facilities prior to impose costs.

Despite all these strategies, Portugal is still far from the targets or the trend is not visible yet because there are no quantitative data about BMW collected.

3. STATE OF ART

In the literature can be found several papers about MSW management. However, studies on the MSW management system review in our country are scarce. So, the aim of this chapter is to survey the work carried out in this area in Portugal.

In the past, waste management options were not the same nationwide and it was necessary a strategic plan to standardize their activities. So, in 1997, the appearance of MSW strategic plan (PERSU I) came to change the view of waste management in Portugal. The main step that was taken to change the waste management was the total closures of dumps, the development of multimunicipal and intermunicipal MSW management systems, and the construction of news infrastructures. Dumps were totally closed only in 2002. Until then, it was impossible to quantify the MSW produced in Portugal due to lack of data available.

In 2003, Pássaro presented a report related to the assessing waste management in Portugal between 1996 and 2002 and describing the principal waste plans and perspectives.

In some studies (Koufodimos and Samaras, 2002), the lack of certain data means that Portugal is only partially represented. In order to create an accurate comparison of indicators across all countries, it is important to standardize all data. Magrinho *et al*. (2006) concluded that in our country there were no consistent data and information about waste generation. In this study, Magrinho and coworkers present the MSW management in mainland Portugal describing the integrated systems to manage this residues. Only after the completely closure of dumps in 2002, there were conditions to obtain credible data. This paper analyses the data regarding 30 MSW management entities (SGRSU) existed in mainland Portugal in 2003. In 2002 the sanitary landfills were the dominant option for MSW disposal. They report that in 2002 the amount of MSW produced in Portugal was 4 746 201 tonnes with 4 553 952 tonnes of mixed waste and 192 062 tonnes of waste separated at source. From the total of waste collected separately only packaging part was sorted (159 621 tonnes), 14 071 tonnes were recovered by composting, 8 447 tonnes by incineration at waste-to-energy (WTE) plants and 9 930 tonnes were disposed in sanitary landfills. In 2002 the average per capita generation rate was 1.32 kg/inhab.day, and this year was the first one that it was possible to quantify the amount of MSW generated in Portugal (Magrinho *et al.*, 2006).

In order to achieve a positive development in terms of reduction and recycling of MSW, and following the progress of European directives it was of the greatest importance to Portugal the new strategic plan calls PERSU II in 2007 (Magrinho *et al.*, 2006). However, from 2006 no studies were carried out to review the MSW management in Portugal. There are only reports from APA regarding infrastructures and equipments (APA, 2010c).

In the literature several studies were carried out involving the application of mathematical models, simple or complex, to compare and evaluate the evolution of the MSW production. An example is the application of life cycle assessment methodology to compare different alternatives for the MSW on environmental point of view (Bovea *et al.*, 2010; Kollikkathara and Stern, 2009; Hanandeh and El-Zein, 2010). Other works use a multi-criteria decision analysis (MCDA) to predict the uncertainty in criteria weightings and threshold values called ELECTRE III (Hanandeh and El-zein, 2010; Karagiannidis and Perkoulidis, 2009). Some studies on management wastes were dedicated to assess the impact of the different treatment options on the greenhouse gas emission (Papageorgiou *et al.*, 2009; Muhle *et al.*, 2010; He *et al.*, 2011). A few studies were devoted to cost benefit analysis to argue about the compatibility of the MSW treatment options (Jamasb and Nepal, 2010).

In 2008, Magrinho and Semião built a scheme of a possible integrated management of MSW involving various stages of management such as sorting, composting, recycling and incineration. From this scheme it was identified various waste streams taking into account those which are reintroduced early in the process. A mathematical model based in a system of equations was set to predict MSW fraction composition of the final mixed stream of MSW going to disposal and its low heat value (LHV) as a function of its initial fraction composition and separate collection at source (Magrinho and Semião, 2008).

Several studies on MSW management in different cities or countries can be used to provide a comparison with the situation in Portugal. Kanat (2010) indicated a study about MSW management in Istambul, Turan *et al*. (2009) addressed MSW management strategies in Turkey, Zhang *et al.* (2010a) developed MSW management in China: Status, problems and challenges, Zhang *et al*. (2010b) indicated a study about comparison of MSWM in Berlin and Singapore and Pires *et al.* (2011) summarized solid waste management in Europe.

4. RESULTS AND DISCUSSION

Since 1995 some data on MSW management has been recorded and published, and this year marked the beginning of MSW management in Portugal.

The supervision of MSW management in Portugal is now under the direction of APA, which is the entity responsible for preparing reports with national data, some of them in association with statistic Portuguese and European entities, such as - INE and EUROSTAT and also with OECD (organization for economic cooperation and development).

Over the past 15 years, the MSW management had a very positive change in Portugal, in part due to the entry into the European Union (in 1986) and consequently with the directives related to this subject. In fact, waste management has only been considered a priority in the 1990s (Pássaro, 2003). Thus, our study intends to analyze the data currently available about the last 15 years, more specifically from 1995 and 2010, with regard to the Portuguese MSW management. This analysis includes MSW physical composition, some specific indicators and also some environmental impacts (e.g. polychlorinated dibenzo-*para*-dioxins and dibenzofurans and carbon footprint).

4.1. Evolution of MSW physical composition

The analysis of waste composition is an important topic to evaluate the potential for valorization. The physical composition is mainly dependent on the collection regions (urban or rural) and season. The methodology and procedure adopted to measure waste composition is important for comparison purposes. MSW composition in mainland Portugal for 1995, 2000, 2005 and 2008 is indicated in Fig. 4.1, where it can be seen that the evolution of waste composition over the years has been stable keeping approximately the same ranges. The main constituents are: organic wastes, paper/cardboard, glass, metal, plastic, wood, textile, and other fine particles. MSW composition is mainly composed by organic waste (about 40%) and paper/cardboard about 20% (APA, 2011b). This means that about 60% of total MSW are biodegradable wastes, hence the diversion of BMW from landfill to organic recovery such composting or anaerobic digestion is an important goal to be achieved in the near future. The percentage values can be observed in Annex A (Tab. A-1).

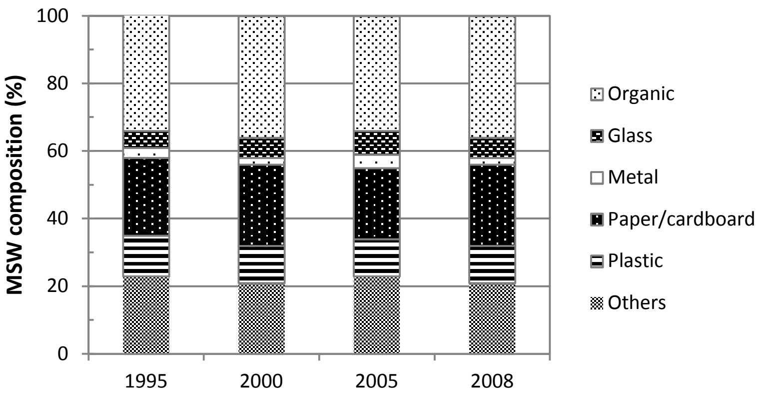


Fig. 4.1 - MSW composition evolution in mainland Portugal (years: 1995, 2000 and 2005, source: OECD, 2011; year 2008, source: APA, 2008).

4.2. Waste management indicators

Waste management indicators require a solid base of data to be relevant. In practice, some indicators are essential for establishing and comparing trends and performance measures. Fig. 4.2 shows the evolution of waste production and waste per capita during the period of analysis defined in this study. With some exceptions both indicators increase over the years. In 1995 were produced around 3.5 million tonnes of MSW in Portugal (OECD, 2011) and in 2010 this value is 5.2 million tonnes (APA, 2011a) which represents an increase of 48.6% from 1995 to 2010. Values of the remaining years can be observed in Annex A (Tab. A-2). In 2001, 2002, 2004 and 2010 both indicators had a slight decrease. In 2006, 2007 and 2008 the observed increase is probably due to the introduction of a new electronic tool, called SIRAPA (Sistema Integrado de Residuos da APA) to record the waste collected by municipal and intermunicipal systems (APA, 2010b). So, from this period forward it is expected that the data are more accurate.

In 1995 the waste per capita was 354 kg/inhab.year, while in 2010 was 512 kg/inhab.year. Thus, the waste per capita had an increase of 44.6%. Although this increase is close to that observed for production, it reveals a positive trend in the behavior of people.

According to INE, in Portugal, the amount of waste collected and wastes per capita between 2004 and 2009 grow at an annual rate of 3% (Ribeiro *et al.,* 2011). In PERSU I a forecast of wastes production was based on an annual of 3% also (MA, 1999).

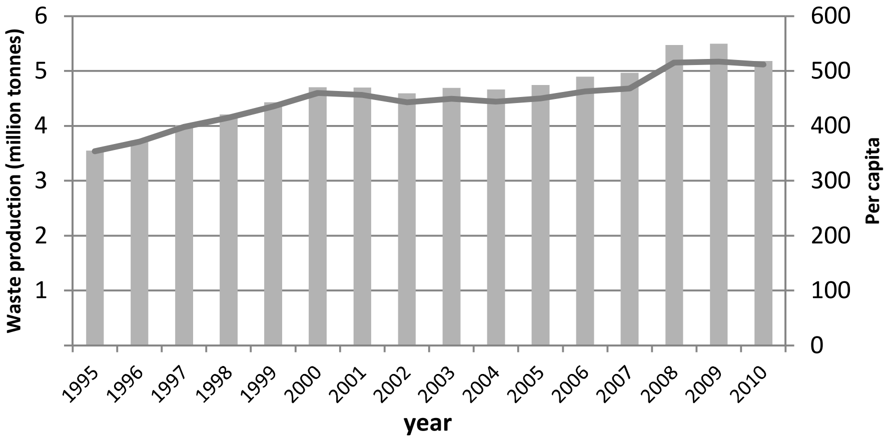


Fig. 4.2 - Waste production and waste per capita in mainland Portugal: 1995 to 2010 (sources: APA 2011a, APA 2011b, INE 2011, PORDATA 2011).

Treatment wastes

Early 1995, most of the wastes produced were deposited in open dumps (around 73%) (MA, 1999). This practice has a negative impact on the environment and on healthy. Gradually, the uncontrolled disposal in dumps was replaced by the landfilling in sanitary sites, until the total eradication in 2002, Fig. 4.3. Despite the hierarchy of waste management require that the landfill should be the last option, in 2010 about 61% of waste still ends up in this type of infrastructure (APA, 2011a).

Energy recovery started in 1999 with the first incineration plant in Portugal at Valorsul, in Lisbon. Nowadays, there are two incineration plants in Portugal, Lipor and Valorsul that together treat about 18% (APA, 2011a) of total MSW produced in mainland Portugal.

In 1995 recycling represent a very short portion of the total waste. This option only re-entered into force in Portugal in 1999 and since then with successive increases. Nowadays recycling achieves about 13% (APA, 2011a) of the total waste treated which is below of expectations (15% according to PERSU II goals).

The organic recovery, through composting processes was implemented in Portugal for several years. From 2003 to 2010 composting has had a slightly increasing trend pushed by ENRRUBDA.

In conclusion, the MSW produced in 2010 were mainly direct towards landfill disposal (61%) followed by energy recovery (18%), organic recovery (13%) and recycling (8%) (APA, 2011a). Values of the remaining years can be observed in Annex A (Tab. A-3). Although h the positive development of wastes recovery, results are still far from the targets. In the future, according to Portuguese and EU policies, the trend must be reduce landfill disposal of and increase recycling and organic recovery. Probably the amount of waste incinerated is expected to remain nearly constant.

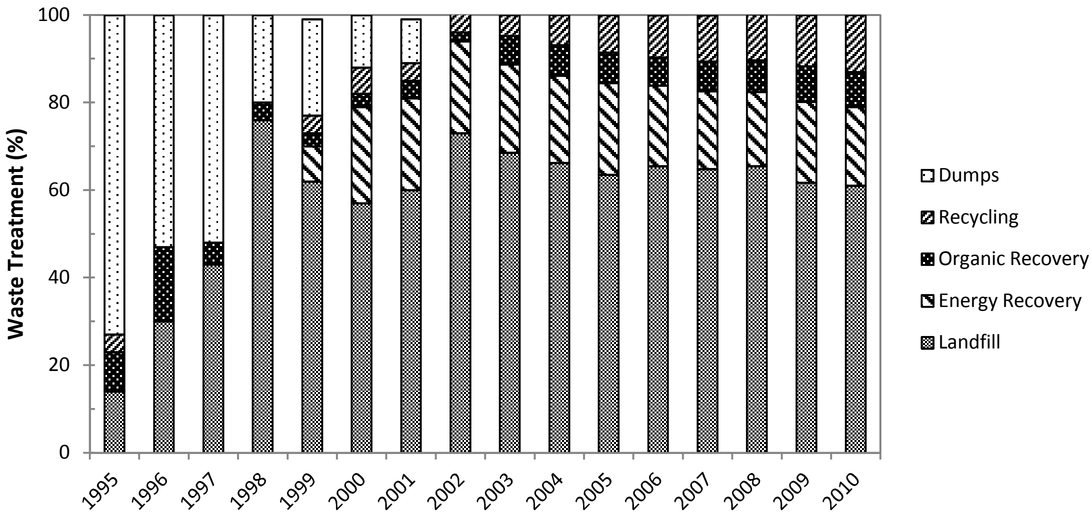
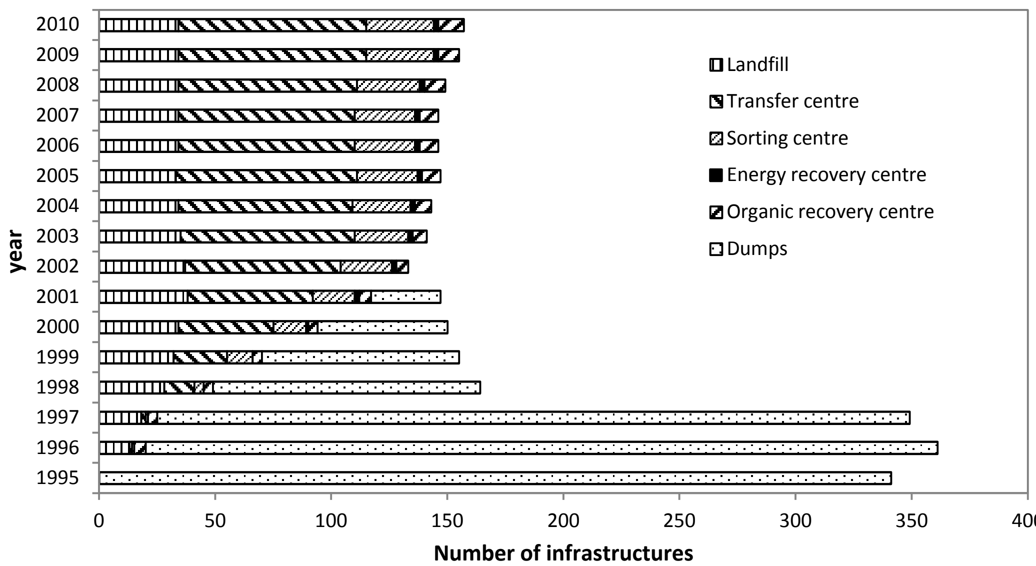


Fig. 4.3 – Waste treatment evolution in mainland Portugal: 1995 to 2010 (sources: APA 2011a, MAOTDR 2007).

The evolution of waste management infrastructures in mainland Portugal from 1995 to 2010 is described in Fig. 4.4. In 1995, there were 341 dump sites, and this number decreased progressively (mainly due to the goals set by PERSU I) until its eradication in 2002. The number of transfer centers, sorting centers, energy and organic recovery centers has been increased over the years mainly due to the goals set by PERSU I and PERSU II concerning the construction of waste treatment infrastructures. In 1995, excluding the numbers of dumps, the numbers of infrastructures was not possible to quantify due to the unavailability of data.



	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Landfill	n.a.	13	18	28	32	34	38	37	35	34	33	34	34	34	34	34
Transfer centre	n.a.	1	2	13	23	41	54	67	75	75	78	76	76	77	81	81
Sorting centre	n.a.	1	1	4	11	14	18	22	23	25	26	26	26	27	29	29
Energy recovery centre	n.a.	0	0	0	0	1	2	2	2	2	2	2	2	2	2	2
Organic Recovery centre	n.a.	5	4	4	4	4	5	5	6	7	8	8	8	9	9	11
Dumps	341	341	324	115	85	56	30	0	0	0	0	0	0	0	0	0

n.a.-not available

Fig. 4.4 –Waste management infrastructures in mainland Portugal: period 1995 to 2010 (sources: IRAR 2008, MAOTDR 2007, APA 2011b).

Fig. 4.5 shows the ecopoints evolution only from 2000 and 2009, since outside this period there are no data available. The ratio of ecopoints per capita allows to know the evolution of separate collection in Portugal. In 2002, in Portugal the average of inhab./ecopoint was 500 (Pássaro, 2003) and this number decrease to 288 in 2009 (APA, 2009) and to 266 inhab./ecopoint in 2010 (APA, 2010c). The decrease of inhab./ecopoints ratio is expected due to the increased of recycling goals.

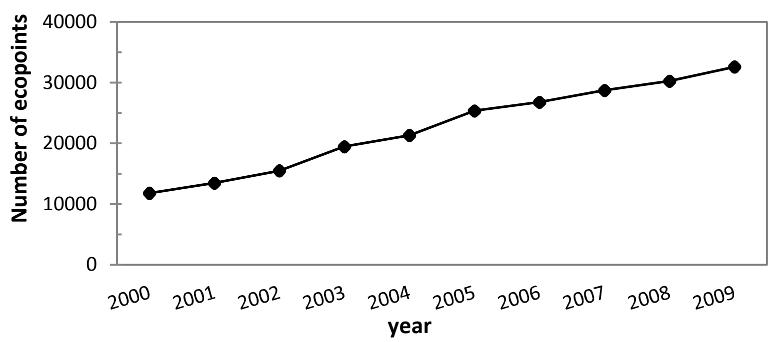


Fig. 4.5 - Ecopoints evolution in mainland Portugal (sources: MAOTDR 2007, ERSAR 2010).

Tab. 4.1 compares the goals of PERSU I and PERSU II with the situation achieved in Portugal. In 1995, MSW management was characterized by total failure of the most basic requirements for environmental preservation, because in 73% of MSW was dumped and 14% was landfilled. It is possible to verify that eradication of dumps and incineration goals established in PERSU I for 2005 were achieved. However, the reduction of waste production established in PERSU I was not accomplished and there was no clear strategy for this goal (Ribeiro *et al.*, 2011). The percentage of waste incinerated has remained almost constant and close to the targets proposed by the strategic plans. The other treatment options are far from the goals proposed by PERSU I and II. Targets for MBT and BMW collection are unknown because no data about the values achieved.

Although not yet possible to compare the results obtained in 2011 with the goals proposed by PERSU II, it is expected to stay away from the targets due to the situation achieved in 2010. It is important to note that Portugal is still far from achieving the goals that are being proposed by the strategic plans. An example is the landfilling goals of 29% and Portugal is currently still disposed of 61% of MSW in landfill sites.

Tab. 4.1 - PERSU I vs PERSU II goals and achievements review (sources: MA, 1999, MAOTDR, 2007).

[%]		PERSU I				PERSU II			
	1995	2000		2005		2009		2011	2010
	Achieved	Goals	Achieved	Goal	Achieved	Goal	Achieved	Goal	Achieved*
Dumps	73	-	12	-	-	-	-	-	-
Landfill	14	41.5	57	23	63	32	62	29	61
Incineration	-	26	22	22	21	21	19	21	18
Recycling	4	15	6	25	9	13	12	15	13
Composting	9	15	3	25	7	25	8	26	8
Reduction	-	2.5	-	5	-	-	-	-	-
TMB	-	-	-	-	-	3	-	1	-
BMW	-	-	-	-	-	6	-	8	-

* APA (2011a).

4.3. Polychlorinated dibenzo-*p*-dioxins and dibenzofurans

In order to evaluate the polychlorinated dibenzo-*para*-dioxins and dibenzofurans (PCDD/F) emissions associated with the MSW management system, a Toolkit methodology of UNEP Chemicals (2005) is used.

The toolkit developed by UNEP Chemicals aims to create an inventory to estimate the dioxins emitted nationally in all categories affected for all member states. Therefore, dioxins releases to air, water, land, products and residues in several technologies or processes are taken into account by using different emission factors.

The Toolkit methodology includes ten possible categories of PCDD/F emissions. However, our study only intended to estimate PCDD/F emissions associated with the different treatments of MSW from 1995 to 2010. Tab. 4.2 shows the main categories and subcategories referred in the toolkit and used in our study. Thus, only categories 1,3,4,7 and 9 were considered. Incineration contributes to PCDD/F emissions into the air and residue. The landfill biogas combustion subcategory contributes with very small amounts of emissions, about 0.04 g TEQ/year (Quina *et al.,* 2011), and thus it is not account. For the same reason, also category 3 and 4 were not accounted. For landfilling subcategory, the emissions into the residue were considered, but releases into the water is minimal, around 0.027 g TEQ/year, 0,5 % of the total emissions (Quina *et al.*, 2011). For composting the main release route is the emissions into the product. Consequently, among the potential categories that contribute to the PCDD/F inventory only emissions from category 1 (incineration) and category 9 (landfilling and composting) were accounted for.

The PCDD/F emissions associated with MSW management was carried out using the spreadsheet from the toolkit (available in: http://www.chem.unep.ch/Pops/pcdd_activities/toolkit/default.htm), where the input data was the amount of MSW.

Tab. 4.2 - Main source categories considered in this study (source: UNEP Chemicals, 2005).

	Release route				
Main categories and subcategories	Air	Water	Land	Product	Residue
Category 1 - waste incineration					
1- a) Incineration	**x**				**x**
Category 3 -heat and power generation					
3- c) Landfill, biogas combustion	x				
Category 4 - Production of mineral products					
4- d) Glass production	x				
Category 7 - Production and use of chemical and consumer goods					
7- a) Pulp and paper production	x	x		x	x
Category 9 - Disposal					
9- a) Landfilling		**x**			**x**
9- d) Composting				**x**	

x - refers to the main release route for each category.

PCDD/F emissions are calculated as a function of the emission factors and activity rate according the following equation (UNEP Chemicals, 2005):

Dioxin emissions (g TEQ/year)=Emission Factor x "Activity Rate" **(4.1)**

where the "emission factor" for each category is associated with each release route (air, water, land, product and residue). The "activity rate" is referred to the production associated with each category. Emission factors used summarized in the Tab. 4.3.

Tab. 4.3 - Emission factors for dioxins releases (source: UNEP Chemical, 2005).

Subcategories	**Emission Factors**					
	Air	Water	Land	Product	Residue	
					Fly ash	Bottom ash
Incineration	0,5 µg TEQ/t MSW burned	-	-	-	15 µg TEQ/t MSW burned	1,5 µg TEQ/t MSW burned
landfilling + Dumping	-	0,03 µgTEQ/ L	-	-	6 µgTEQ/ t waste deposited	
Composting	-	-	-	15 µgTEQ/t dry matter		-

Tab. 4.4 shows the results of PCDD/F emissions obtained from 1995 to 2010. In 2010 the annual PCDD/F emissions associated with incineration were 15.9 g TEQ/year. About 97% of these emissions were released to residue and the contribution into the air are very small (0.47g TEQ). As previously stated, the emissions associated with landfill were calculated only for the residues, because the contribution to the water route was not significant.

Around 19 g TEQ were emitted in 2010. Emissions associated with composting of MSW were significantly lower, about 2.2 g TEQ in 2010. Overall, it can be concluded that the treatment phase of MSW associated with the highest PCDD/F emissions is landfilling.

Tab. 4.4 – PCDD/F emissions over the years according toolkit methodology.

(gTEQ/year)	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Incineration																
Air	0	0	0	0	0,18	0,52	0,49	0,48	0,47	0,47	0,50	0,45	0,44	0,46	0,51	0,47
Residue	0	0	0	0	5,85	17,07	16,27	15,92	15,62	15,36	16,44	14,87	14,59	15,26	16,78	15,40
total	**0**	**0**	**0**	**0**	**6,0**	**17,6**	**16,8**	**16,4**	**16,1**	**15,8**	**16,9**	**15,3**	**15,0**	**15,7**	**17,3**	**15,9**
Landfilling and dumping																
Residue	**18,5**	**18,6**	**22,9**	**24,2**	**22,3**	**19,5**	**19,7**	**20,1**	**19,3**	**18,5**	**18,1**	**19,2**	**19,3**	**21,5**	**20,3**	**19,0**
Composting																
Product	**1,7**	**3,3**	**1,1**	**0,9**	**0,7**	**0,7**	**1,0**	**0,5**	**1,6**	**1,7**	**1,7**	**1,6**	**1,8**	**2,1**	**2,3**	**2,2**
TOTAL	**20,2**	**21,9**	**24,0**	**25,1**	**29,0**	**37,8**	**37,5**	**37,0**	**37,0**	**36,1**	**36,7**	**36,2**	**36,1**	**39,3**	**40,0**	**37,0**

TEQ - Toxic equivalent.

The PCDD/F emissions evolution over the years is compared in Fig. 4.6. The largest sources of PCDD/F emissions are associated with incineration and disposal in landfills and old dumps.

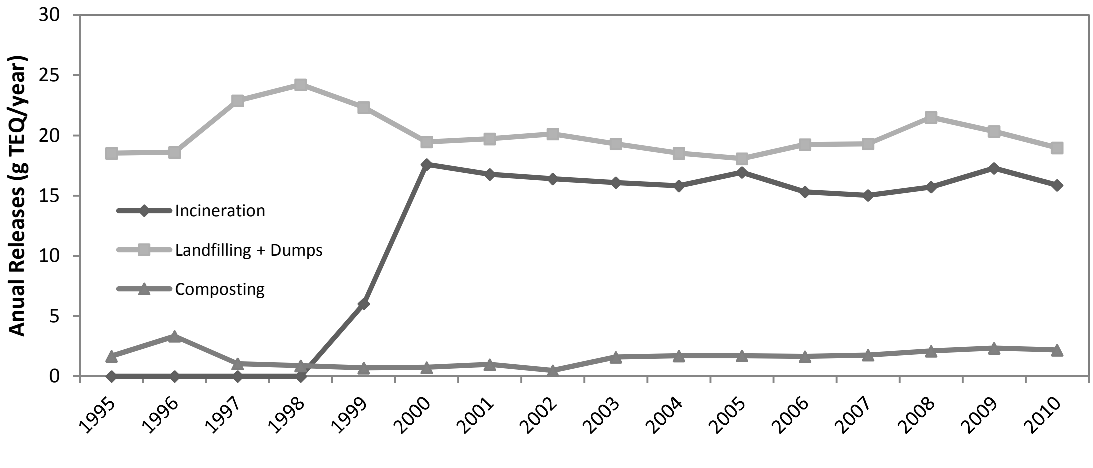


Fig. 4.6 – PCDD/F annual emissions in Portugal associated with MSW treatments.

4.4. Assessment of carbon footprint associated to waste management options

The total amount of greenhouse gases (GHG) associated with each MSW management option is evaluated and compared in this section. GHG are estimated from the annual amount of wastes treated by each technology (landfilling, incineration, composting and recycling) using the emission factors proposed by Smith *et al.* (2001).

The model defined by Smith *et al.* (2001) for the calculation of emission factors involves several processes. Among these are the emissions of methane (CH4) associated with the disposal of biodegradable waste and emissions of nitrous oxide (N_2O) associated with waste incineration. The emissions of carbon dioxide (CO_2) associated with transport of waste from site production to the respective treatment, process itself, and from the incineration of plastics, are also considered. All these emissions described above contribute to a positive flux of greenhouse effect. However, there are some processes that lead to a negative flux of greenhouse gases, i.e., a positive impact. This applies to the energy harnessed through incineration replacing the use of fossil fuels, the emissions avoided by recycling materials recovery, composting avoided emissions associated with the substitution of compost for fertilizer, and also the process of sequestration carbon. Carbon sequestration was defined in the Kyoto Conference in 1997 and concerns the capturing and storing carbon dioxide in the surface of Earth in a longer time horizon of 100 years. Thus, this process is only taken into account in landfills due to the slow degradation of the carbon stored in the landfill, and in composting due to the carbon that is stored in the soil, incorporated into the stable compound. The sum of all these positive and negative fluxes led to the total fluxes of potential greenhouse gas emissions factors associated with MSW management, calculated by Smith *et al*. (2001). The processes associated with each technology are summarized in Tab. 4.5.

Tab. 4.5 - Principal processes quantified by Smith *et al.*(2001) to assess waste management options on climate change.

	Landfilling	Incineration	Composting	Recycling
N_2O Emissions	-	x	-	-
CH_4 Emissions	x	-	-	-
Carbon sequestred	x	-	x	-
Transport CO_2	x	x	x	x
Avoided energy and materials	x	x	x	x
Energy use CO_2	x	-	x	x
Process CO_2	-	x	-	-

Landfilling

The main contributors to environmental impact from landfill are the emissions of methane (CH_4) and the carbon sequestration of carbon in the landfill. The carbon footprint associated with landfill can be estimated using the average European emission factor for the year 2000 which is 328 kg CO_2 eq/tonne MSW (Smith *et al.*, 2001). However, in open literature, two limit values for carbon degradation are proposed a high dissimilable degradable organic carbon (DDOC) and low DDOC. DDOC value represents the proportion of degradable organic carbon content (DOC) dissimilated or mineralized during 100 years. Fig. 4.7 shows the evolution of the potential carbon footprint for the period from 1995 to 2010. In 2010, the average value it was 1.04×10^9 kg CO_2 eq in 2010, the estimation according to high DDOC was 1.84×10^9, and for low DDOC 1.33×10^8.

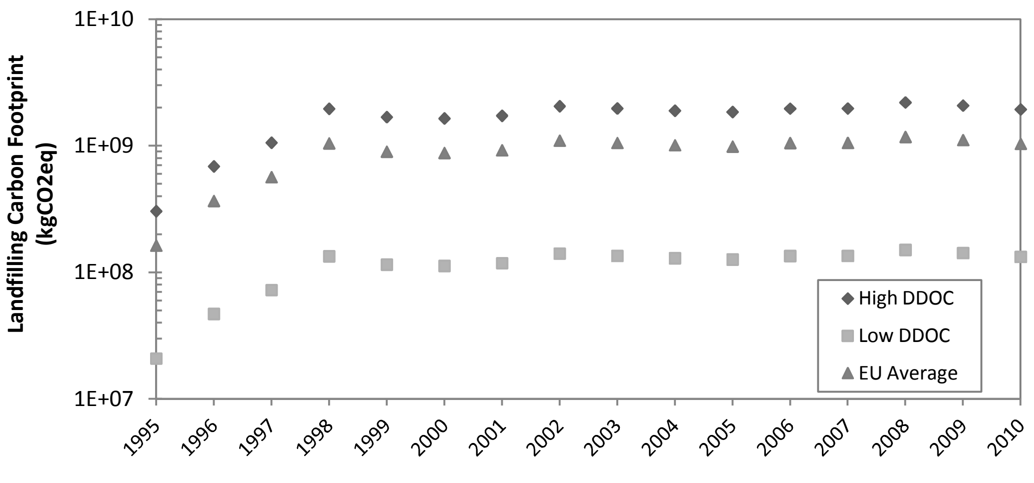


Fig. 4.7 – Potential landfill carbon footprint over the period 1995-2010 for three scenarios.

Incineration

The breakdown of greenhouse gas fluxes from incineration depends strongly on the material being combusted. When paper is incinerated and energy recovered as electricity, a negative net flux occurs when compared to fossil CO_2, but for plastic waste a net positive flux is observed (Smith *et al.*, 2001).

To estimate carbon footprint associated with MSW incineration when energy recovery as electricity is considered it was adopted the EU average emissions for the year 2000 (-10 kg CO_2 eq/tonne MSW) (Smith *et al.*, 2001). The energy recovery makes a substantial contribution to the negative GHG flux. A comparison with two alternatives: substitution of electricity from coal (scenario A) and replacement of the electricity produced by wind turbines (scenario B) allows to conclude that electricity from coal replacement has a negative flux, meaning less fossil fuels. In opposition scenario B provides a positive GHG flux as result of the approach to a sustainable environmental practice. Fig. 4.8 provide a comparison between the three scenarios. In 2010, the total amount of CO_2 eq emitted to the atmosphere was around -9x10^6 kg. For scenario A the released amount was -2.1x10^8 and for scenario B was 1.65x10^8 kg CO_2 eq.

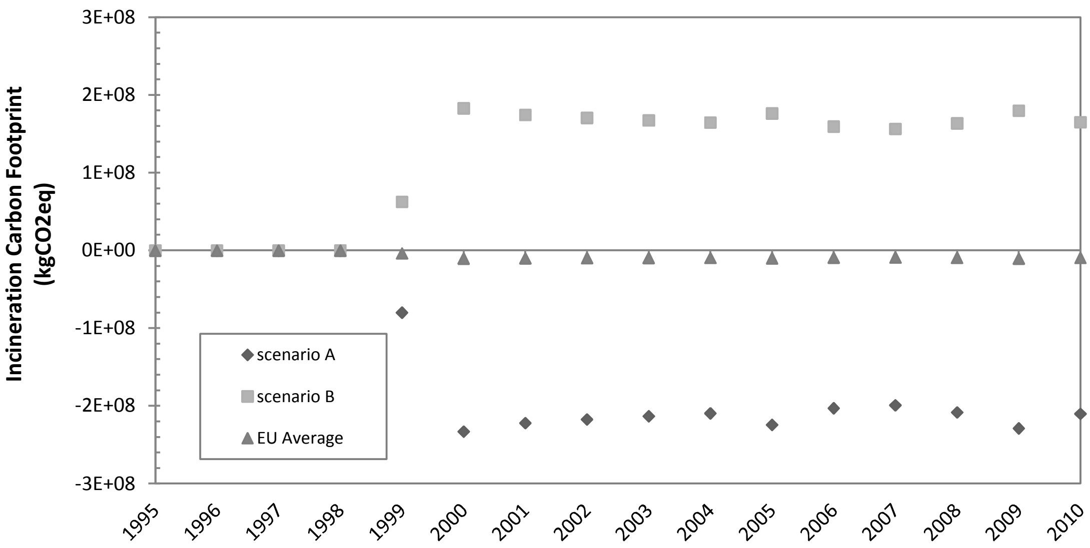


Fig. 4.8 - Potential incineration carbon footprint over the period 1995 – 2010 for three scenarios.

Composting

Contribution of composting to GHG flux is mainly related with the materials and energy avoided due to the replacement of chemical fertilizer by the compost, as well as the carbon sequestration in soil. Despite of several assumptions for the treatment of putrescible wastes in the study by Smith *et al.* (2001), it was assumed that only open composting takes place in Portugal. To estimate CF associated with MSW composting, it was adopted de EU average emissions for the year 2000 as -12 kg CO2 eq/tonne MSW (Smith *et al.,* 2001) to calculate the potential GHG flux in Portugal over the period 1995 – 2010. In 2010, the total amount of CO_2 eq emitted to the atmosphere was around -4.9x10^6 kg.

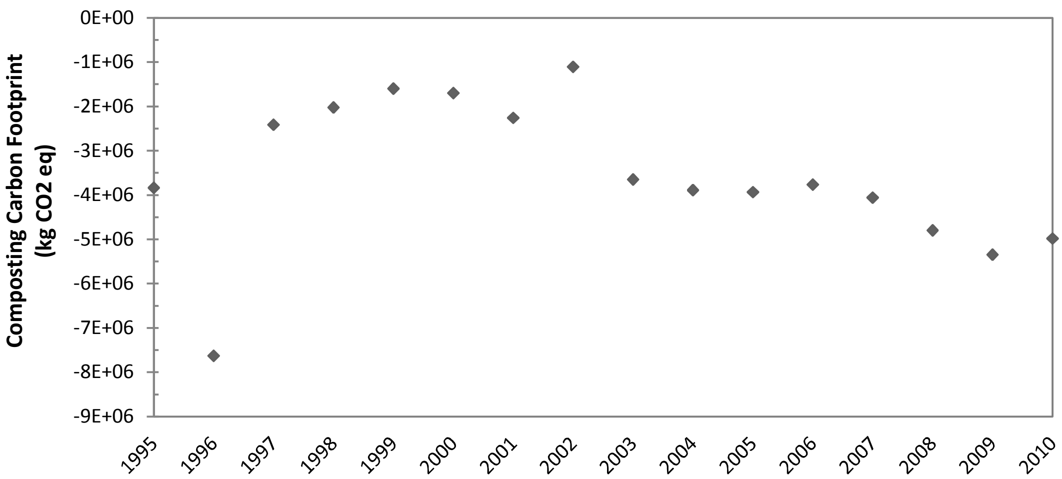


Fig. 4.9 - Potential composting carbon footprint over the period 1995 - 2010.

Recycling

The main contributions to GHG flux in recycling process are materials and energy avoided, due to the conversion of recycled material into new products. The European average of GHG emissions associated with total MSW recycled calculated in Smith *et al.*(2001) was -467 kg CO2 eq/tonne MSW. The literature also presents emission factors for the variation that exists on total recycling refuges that are deposited in landfill. However, it was not taken into account in this study due to lack of national quantities of these fractions. Based on this ratio, the potential carbon footprint associated with the recycling of MSW in

Portugal was estimated (Fig. 4.10). In 2010, GHG flux emitted was around -3,1x10^8 kg CO_2 eq. The years 1996, 1997 and 1998 are not representing due to the lack of data.

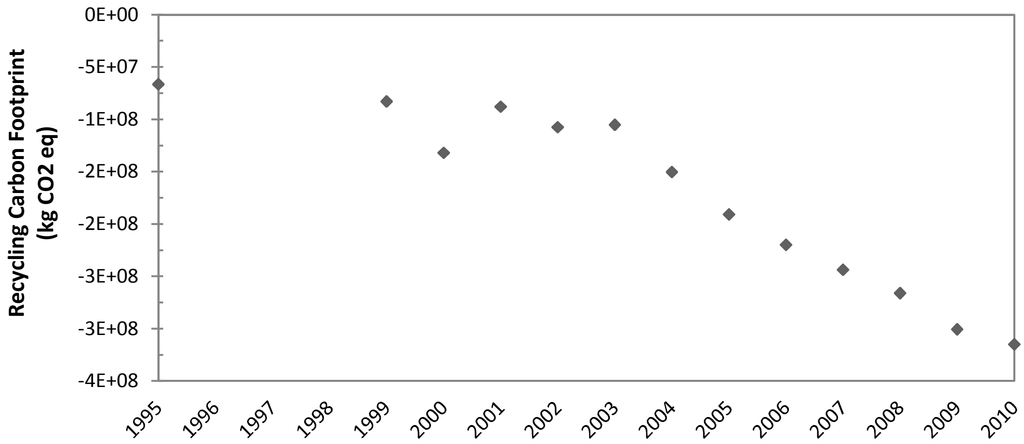


Fig. 4.10 - Potential recycling carbon footprint over the period 1995 - 2010.

Fig. 4.11 shows the total carbon footprint associated with MSW management in Portugal over the period 1995 - 2010. It is possible to verify that the major contribution for the carbon footprint on MSW management is landfilling. Incineration, composting and recycling contributes with negative flow of carbon footprint due to the carbon sequestration and energy and materials avoided. The total carbon footprint associated with MSW option treatments gives the annual average. In 1995, 1x10^8 kg CO_2 eq. was emitted, and in 2010 this value was around 7x10^8 kg CO_2 eq. The potential increase of GHG emissions over the years is proportional to the MSW production, as expected. To validate the data, a comparison of results obtained with the existing literature is carried out using GHG emissions expressed in kg CO2 eq associated with all sectors in Portugal (APA, 2011c) excluding 2010 due to the lack of data. In Portugal, total GHG emissions without land use, land use change and forestry (LULUCF[1]) for 2009 were estimated at about 74.6x10^9 kg CO2 eq (APA, 2011c). In 2007 for Portugal, the total GHG flux estimated was 81.9x10^9 kg CO2 eq according European Commission (2010), and about 79.1x10^9 kg CO2 eq according APA (2011c). The same order of magnitude shows that the values are reliable. From 1995 to 1998 GHG flux associated with waste management increased at almost constant rate. Between 1998 and 2005 GHG flux remained below the maximum

[1] LULUCF – Land use and land use change and forestry is a factor that contributes to the global warming and climate change phenomenon and for carbon sequestration

value achieved in 1998 with up and down variations. Since 2005 a slight decrease of total GHG emissions has been observed, in spite of growing MSW generation, regarding better MSW management (Bakas *et al*., 2011).

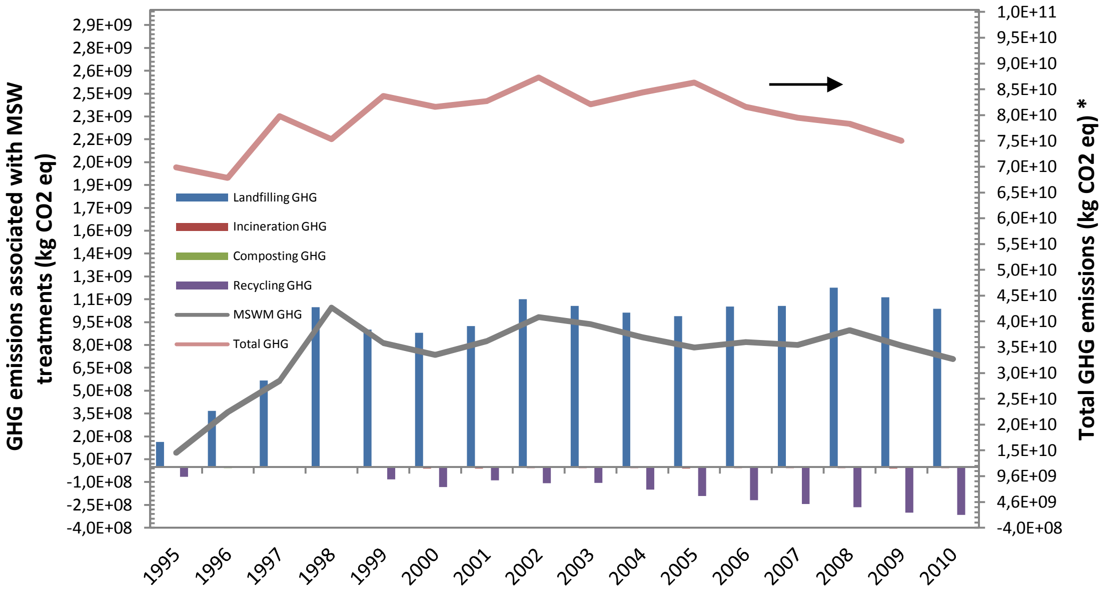


Fig. 4.11 – Comparison of total carbon footprint associated with MSW management from 1995 to 2010, and the total GHG emitted in Portugal(*APA, 2011c).

According to PNAC (2006), Portugal has compromised to limit GHG emissions growth by 27% (compared to base year 1990) between 2008 and 2012. In 1990 the total GHG emissions estimated was $59.4x10^9$ kg CO2 eq (APA, 2011c) so, it means a limit of $75x10^9$ kg CO_2 eq of GHG emitted from 2008 to 2012. It is possible to verify that despite the slight reduction of GHG emissions currently observed, those targets are being achieved.

The accumulated total GHG emissions percentage associated with waste management and the associated with other sectors of activity in Portugal are compared in Fig. 4.12, for 2009. The results show clearly that the main source of GHGs in Portugal is the energy sector (71.9%).

The wastes sector contributes with 10.3% to the total GHG emissions (excluding LULUCF), in 2009. According APA (2011c), in 1990, GHG emissions with wastes sector was about 10.1%.

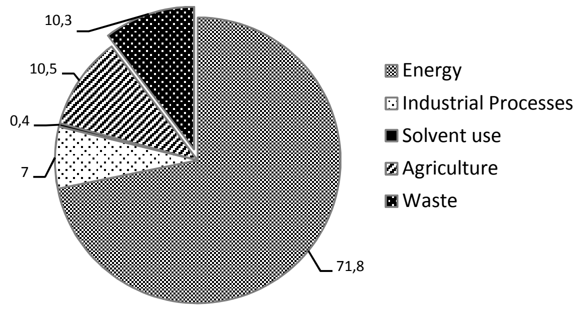


Fig. 4.12- GHG emissions by sector in 2009 (source: APA, 2011c).

So, the percentage contribution of GHG associated with MSW management in Portugal, to the total emissions of GHG, is considered in Fig. 4.13 where a comparison between the average GHG emissions all over the years and the annual GHG emissions (for 2009) is given from 1995 to 2009 (2010 was not accounted due to the lack of GHG emissions data). The GHG emissions associated with MSW management in mainland Portugal is about 1% over the years, excluding 1995 to 1997. The GHG emissions associated with waste sector includes waste management and treatment of industrial and municipal wastes. Thus, the remaining percentages of GHG emissions are associated with industrial waste.

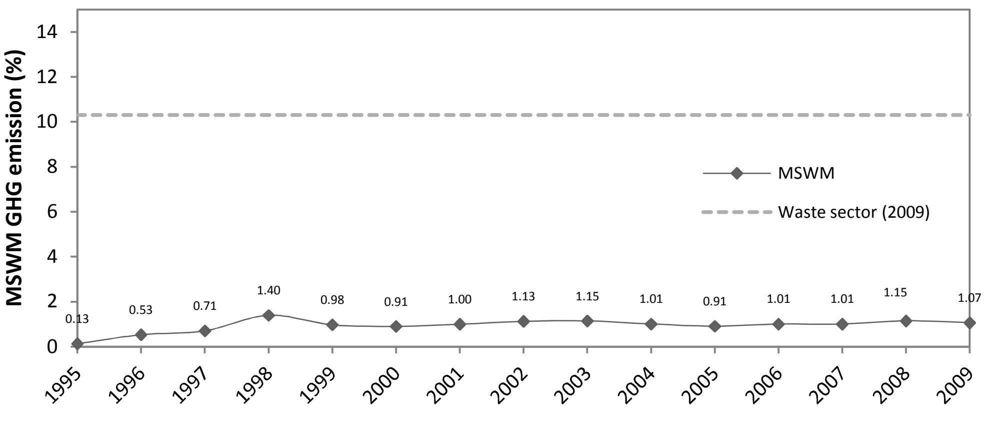


Fig. 4.13 – MSW management contribution to the total GHG emissions associated to waste sector.

Concluding, the contribution of carbon footprint related with MSW management has been low, from 1995 to 2009, and represent around 1% of the global emissions.

For reference, direct GHG emissions from MSW management, in 2007, represent around 2.6% (not include recycling) of the total GHG emissions in EU-15 (Bakas *et al.*, 2011; Bogner *et al.*, 2007).

4.5. Overview comparison of MSW management in Europe

The hierarchy of waste management proposed by the Directive 2008/98/EC has been the policy line at national and European level. All developed countries have been adopting these guidelines, promoting an environmentally sustainable waste management and encouraging energy recovery

It is important to collect data at European level in order to draw up plans of action depending on the trends observed. Fig. 4.14 shows the evolution of MSW treatment options in EU-27 in the period 1995 - 2009. No data is available for 2010. In this scope, it is important to note that landfilling has decreased steadily over the years. In fact, in 1995 almost 70% of MSW was disposed of and in 2009 this figure reached less than 40%. On the contrary, the recovery options incineration, recycling and composting has got a gradual increase over.

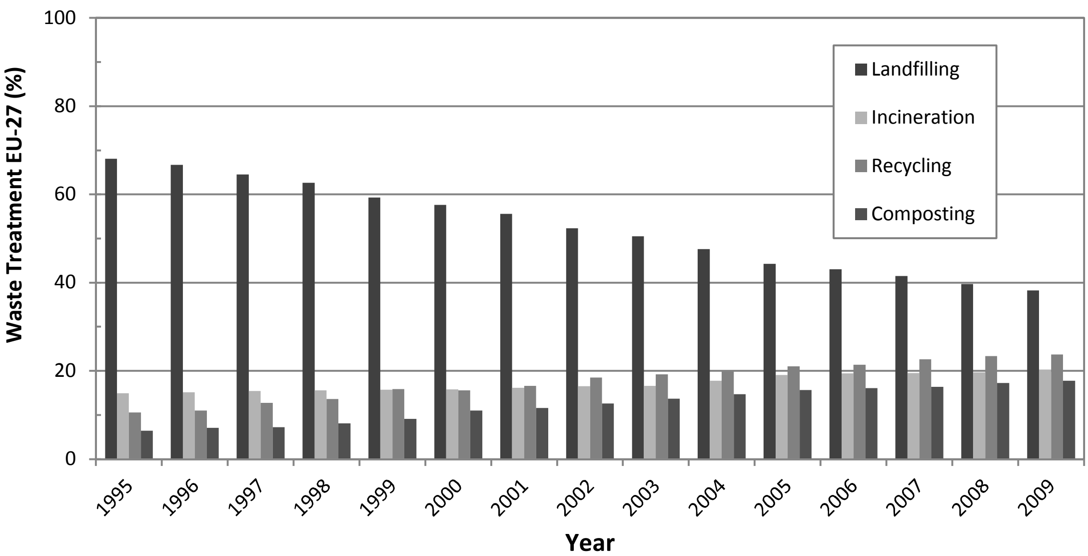


Fig. 4.14 – MSW treatment options evolution in EU-27 in the period 1995 to 2009 (source: EUROSTAT, 2011b).

To understand the developments of European waste management treatments, the EU-15 results are represented in Fig. 4.15 for the years 1995, 2000, 2005 and 2009. In 1995 and 2000, Greece (EL) and Finland (FI) were not represented due to lack of data. Since 1995, in EU, a tendency for increase recycling and composting and decrease landfilling has been observed. In 2009, two distinct groups can be observed: countries mostly supported in landfills (IE, EE, EL); countries mainly adopting composting and recycling at most final treatment option of MSW (AT, DE, BE, SE, DK, NL). The other countries approach the European average. Portugal is close to EU average regarding incineration, but is about 30% below the EU average in recycling+composting. Regarding landfilling Portugal is 30% higher than the EU average.

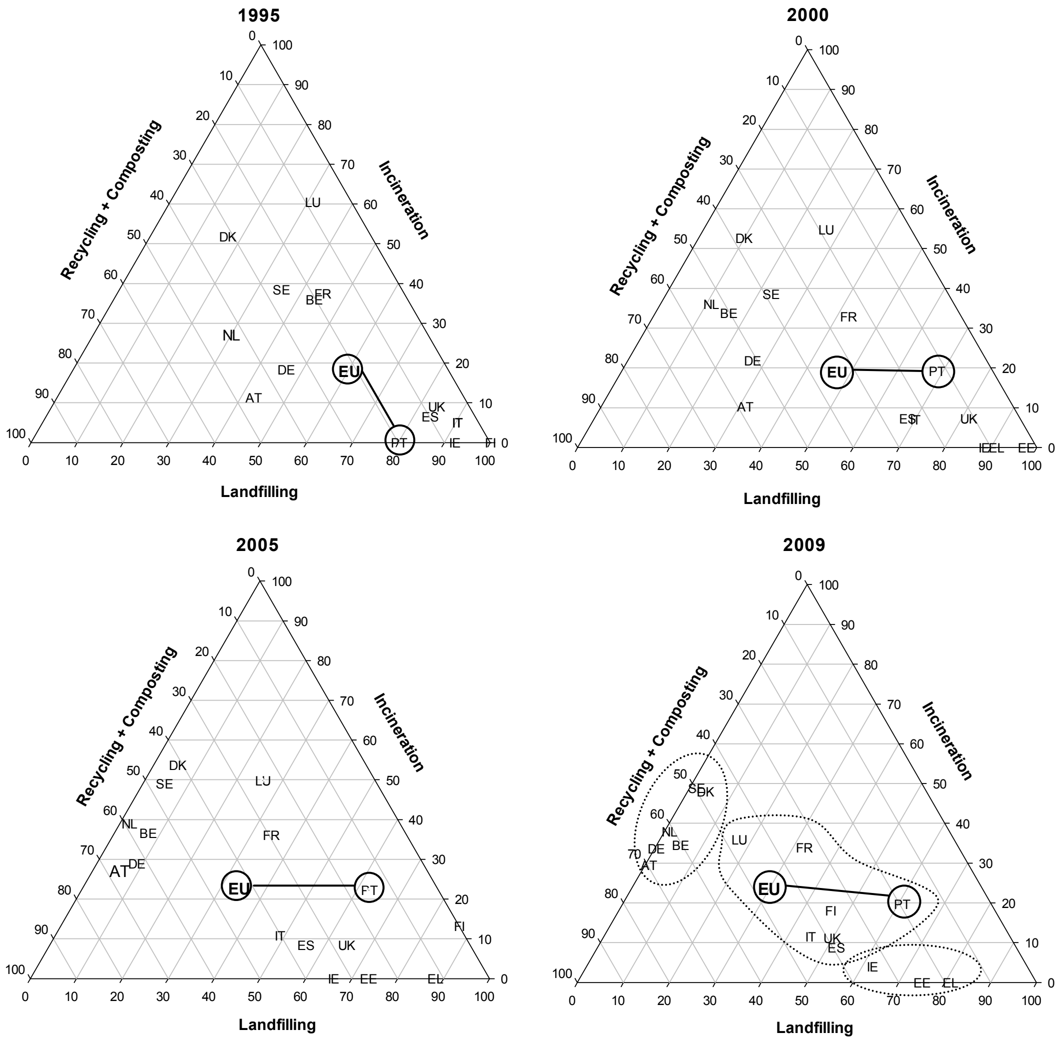


Fig. 4.15 - MSW treatment options variation in EU-15 over the years (source: EUROSTAT, 2011b).

DK-Denmark; LU-Luxembourg; SE-Sweden; BE-Belgium; FR-France; DE- Germany; AT-Austria; PT-Portugal; UK-United Kingdom; FI-Finland; IT-Italy; ES-Spain; IE-Ireland; EL-Greece; NL- the Netherlands; EU-European Union.

According to Koufodimos and Samaras (2002) recycling was the most positive practice of waste management, followed by composting and incineration.

The annual average production per capita in all countries of the European Union can be compared in Fig. 4.16. Among the several countries, the lowest and highest average annual value per capita belongs to Greece, EL (457 kg/inhab.year) and Denmark, DK (881 kg/inhab.year), respectively. In 2009, Portugal is close to EU-15 average, with an average annual production of 517 kg/inhab.year.

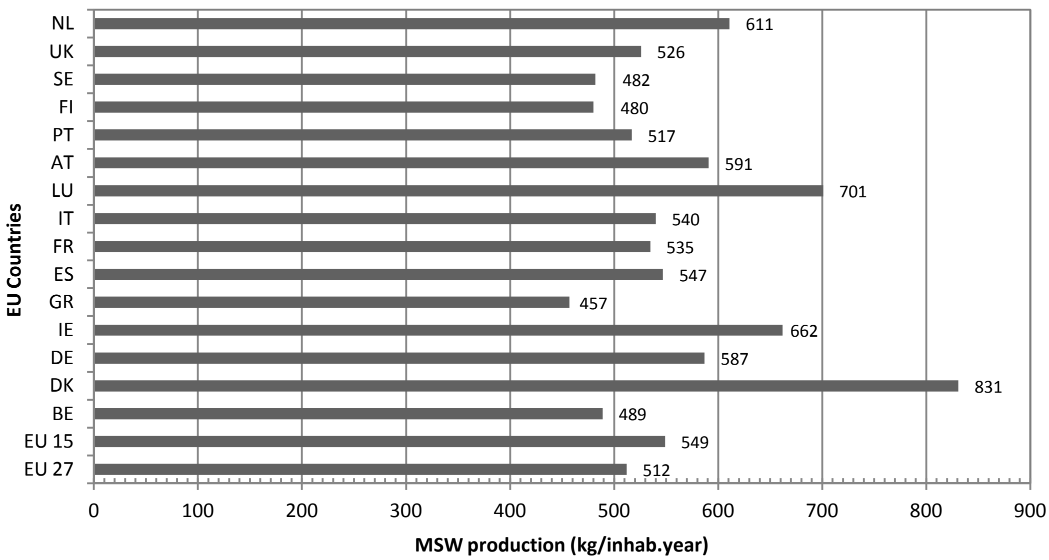


Fig. 4.16 – Annual production of MSW per inhabitant in EU countries in 2009 (source:EUROSTAT, 2011b).

The great question proposed by European Environment Agency in 2011(EEA, 2011) was *"Are we reducing the generation of municipal waste?"*. Despite EU directives and strategic plans, the situation in Europe is far to be uniform and minimum targets must be proposed.

4.6. Trends for waste management system

In order to design the future of MSW management it is important to indicate the trends for MSW management systems in Europe and in Portugal. Bakas *et al.* (2011) has developed a model to predict the amount of waste and management options in the EU countries. Fig. 4.17 shows the results obtained for landfilling and incineration over the period 2011 to 2020. Landfilling is predicted to decrease in Portugal about 12% in, when 7% is predicted for EU-27. A similar increase is predicted for incineration. However, from 2008 to 2020, the MSW quantities will increase near 8.1% in Portugal. Bogner *et al.* (2007) referred that these trends are mainly due to the landfill directive, which requires biodegradable wastes to be diverted from landfills. These authors also expected an increase on waste minimization, recycling, re-use and energy recovery.

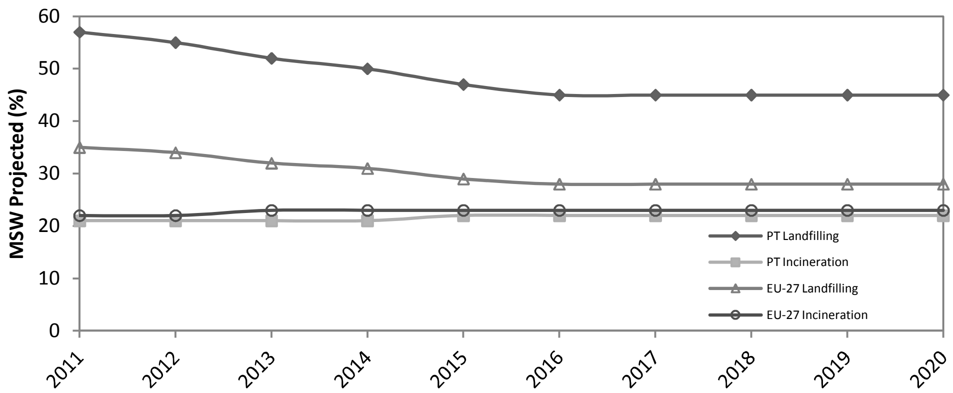


Fig. 4.17- MSW projected to be landfilled and incinerated for PT and EU-27 from 2011 to 2020 (source: Bakas *et al.*, 2011).

PNGR (2011) in line with other European policies and strategies has developed objectives to achieve by 2020. Targets to accomplish these objectives were proposed and mainly associated with performance indicators summarized in Tab. 4.6. The concept of integrated waste management (IWM) combines all those measures and proposed guidelines. The waste streams, collection methods, treatment and disposal and the implementation of the waste management hierarchy contribute to the achievement of environmental benefits.

Tab. 4.6 - Objectives and targets for 2011 - 2020 (adapted by PNGR, 2011).

Objectives	Targets
a) Promote the efficient use of natural resources in the economy	1- Decoupling economic growth from material consumption; 2- Decoupling economic growth from waste generation; 3- Larger integration of waste in the economy.
b) Reduce the adverse impacts of waste production and management	4- Reducing waste production; 5- Reducing the amount of waste disposed of; 6- Reducing GHG emissions in the waste sector.

The increasing quantity of waste in Portugal has been closed to the EU average (PNGR, 2011). Waste treatments options in Portugal concerning recycling and recovery have reached low levels when compared to EU average (Fig. 4.15). According PNGR (2011) the high rates of landfill diversion in Germany, Sweden and Netherlands are due to the application of high penalties for landfill disposal.

According the levels achieved for waste treatments options under the hierarchy established for waste management the European Environmental Agency (EEA), classified EU countries into three typologies (Tab. 4.7).

Tab. 4.7 - Countries groups according level achieved for waste treatments (source: EEA, 2007).

Group	Typology	Countries
Group 1	High recovery and incineration Low landfill disposal	Denmark, Sweden, France, Belgium, Netherlands and Luxembourg.
Group 2	High recovery Medium incineration and landfill	Austria, Finland, Germany, Hungary, Italy, Ireland and Spain.
Group 3	Low recovery and incineration High landfill disposal	Cyprus, Czech Republic, Estonia, Greece, Latvia, Lithuania, Malta, Poland, Slovakia and Slovenia.* United Kingdom, Greece and Portugal.**

* New members states
** Member states that had extension of the Landfill Directive deadlines

Portugal belongs to the group 3 with low recovery and incineration levels and high levels of landfill disposal. Effective mechanisms need to be put into place in Portugal to ensure an approach to the best practice in wastes management.

5. CONCLUSION AND FUTURE WORK

The Portuguese MSW management system was analysed in the period of 1995 to 2010. An overview over the years was conducted describing evolution of recycling, incineration, composting and landfilling, specifying some ratios such as MSW/inhab.year and the infrastructures available. The trend on waste management and influence of MSW strategic plans and legislation in Portugal on the wastes management system was also analyzed. Climate changes associated with greenhouse gas and polychlorinated dibenzo-*para*-dioxins and dibenzofurans emissions were analysed.

The study revealed that in 2010 were produced about 5.2 million tonnes of MSW with an annual production of 512 kg/inhab. Despite existing slight decreases during horizon plan, overall MSW production has increased from year to year and wastes produced increased 48.6% from 1995 to 2010. Analysis of treatments options and technologies regarding MSW management revealed that in 2010 the main final destination was landfill disposal (61%), followed by energy recovery (18%), organic recovery (13%) and recycling (8%). The current situation is completely different from 1995 where 73% of total MSW were disposed of in open dumps. Over the years the landfilling has been decreasing and recycling has increased. The number of infrastructures devoted to energy and organic recovery has increased. Of the 341 open dumps existing in 1995 were all closed at early 2002. This is due to the practice of PERSU I goals. Portugal is far from reaching the goals proposed by PERSU II. Only incineration ratio is close to the target proposed by the strategic plan and the EU average. The other MSW treatment options are far from the goals.

The second goal of this study was to quantify PCDD/F (g TEQ/year) releases and GHG (kg CO_2 eq) emissions emitted due to the several technologies associated with MSW management system. The Carbon footprint associated to MSW management was calculated from the total GHG emissions expressed in kg CO_2 eq. In mainland Portugal, the potential CF associated with MSW management was $7x10^8$ kg CO_2 eq, in 2010.

The major contributors to GHG emissions were landfills due to CH_4 emissions. The contribution of MSW management for the total GHG emissions in Portugal contributes is around 1% of total GHG emissions.

Despite all strategic plans most of MSW in Portugal is send to landfill, which is far of EU-27 average of 40%, and consequently produce higher environmental impact. In conclusion, our analysis showed that the current MSW management system results in Portugal are not sustainable when compared with European average.

5.1. Future work

In the course of this work, there were some aspects that can be improved in future investigations, as well as others which may complete the study. So, some suggestions for future work are presented below.

This study was only carried out for mainland Portugal due to lack of data for archipelagos of Azores and Madeira. Thus, the future work should be improved on data collection for all territory in order to cover as much as possible the Portuguese WMS.

To complement this study the methodology of Carbon footprint should be compared with other EU countries. An investigation into the contribution of GHG emissions associated with MSW management could be applied in order to validate and compare the results from Portugal.

In literature several studies were carried out on application of mathematical models, to compare and evaluate MSW production evolution. An integrated management of MSW would be helpful in considerably mitigation GHG emissions. A bilevel decision-making supporting two non compromised objectives could be approached. For example management cost minimization and GHG emissions reduction maximization could be indentified to examine the pros and cons of the decisions applied in Portuguese case study supported by He, *et al.* (2011).

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ANNEX A – WASTES VALUES

The tables below shows waste composition (1995, 2000, 2005 and 2008), waste production and wastes per capita and also treatment wastes evolution in mainland Portugal: 1995 to 2010.

Tab. A-1 - MSW composition evolution in mainland Portugal (years: 1995, 2000 and 2005, source: OECD, 2011; year 2008, source: APA, 2008).

(%)	1995	2000	2005	2008
Organics	35	36	34	36
paper	23	24	21	24
textile and others	23	21	23	21
plastics	12	11	11	11
metal	3	2	4	2
glass	5	6	7	6

Tab. A-2 - Waste production and waste per capita in mainland Portugal: 1995 to 2010 (sources: APA 2011a, APA 2011b, INE 2011, PORDATA 2011).

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
WASTE PRODUCTION (million tonnes)	3,5	3,7	4,0	4,2	4,4	4,7	4,7	4,6	4,7	4,7	4,7	4,9	5,0	5,5	5,5	5,2
WASTE PER CAPITA (Kg/inhab.year)	353,8	371,4	398,1	415,2	435,4	459,8	456,2	443,2	449,5	444,2	449,8	462,8	468,2	515,1	516,9	512

Tab. A-3 - Waste treatment evolution in mainland Portugal: 1995 to 2010 (sources: APA 2011a, MAOTDR 2007).

(%)	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Landfill	14	30	43	76	62	57	60	73	69	66	64	66	65	66	62	61
Energy Recovery	0	0	0	0	8	22	21	21	20	20	21	18	18	17	19	18
Organic Recovery	9	17	5	4	3	3	4	2	6	7	7	6	7	7	8	8
Recycling	4	0	0	0	4	6	4	5	5	7	9	10	11	10	12	13
Dumps	73	53	52	20	22	12	10	0	0	0	0	0	0	0	0	0