THE EFFECT ON THE GHG EMISSIONS AND ENERGY CONSUMPTION OF MSW MANAGEMENT PRACTICES ON PORTO CITY

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ABSTRACT
The present case study was developed for the municipality of Porto, the second largest city of Portugal that has near 300 000 inhabitants. Due to legislative evolution, some changes have been implemented on MSW management practices since 1990 leading to meaningful improvements on energy consumption and greenhouse gases emissions.

Two situations were compared: (i) the first one concerns the situation in 1990 where the MSW produced was collected, a meaningful fraction of it was composted and the residual waste dumped; and, (ii) the second situation where the EU legislation on recycling targets for packaging material and diversion of organic waste from landfills was taken into account, including an incineration plant on the management system. Greenhouse gas emissions from these two management scenarios were calculated based on an inventory model developed by White et al (1992). Weighting factors for the different gases based on the recommendations of the Intergovernmental Panel on Climate Change were used to aggregate the emissions values and obtain a simple and comparable result for each situation. Results show the advantage of the 2000 practices both in terms of energy consumption and emissions of gases with greenhouse effect.

INTRODUCTION
In developed countries, waste management is governed by legislation. The European Commission recognizes the need of selecting management options taking into account the possible risks to human health and the environment (1). Based on the general legal framework, the community policy on waste is supplemented by a number of more specific directives that may be divided into two groups: (i) directives aimed at reducing the impact of treatment and disposal by setting common technical standards for operation of treatment facilities as the directive on incineration (2000/76/EC) and the landfill directive (99/31/EC); and, (ii) directives on specific waste streams covering both measures of prevention and common rules for separate collection and treatment, in particular the packaging and packaging waste directive (94/62/EC), among others (2).

The landfill directive states that biodegradable municipal solid waste landfilling must be reduced to 75% by 2006 (compared to 1995 levels), dropping to 50% by 2009 and 35% by 2016. Member states that landfill over 80% of their MSW may postpone these targets by a period not exceeding 4 years (3).

One of the waste streams that the European Union gives special attention is packaging. The packaging directive includes measures aimed at preventing waste generation and increasing the recovery and recycling of packaging waste. This directive sets three targets. Target 1 requires

Member States to reach a recovery level between 50% and 65% by weight of all packaging wastes. Recovery covers all kinds of recycling, energy recovery and composting. For achieving Target 2, Member States must reach a recycling level of between 25% as a minimum and 45% as a maximum by weight of all packaging waste. The obligation for Target 3 is reaching a minimum recycling level of 15% on specific packaging waste materials (4). This legislation resulted in many changes on the waste management practices in Europe and obviously also in Portugal.

The present case study was developed for the municipality of Porto, the second largest city of Portugal located in the north of the country on the western coast. In Portugal, the MSW management is committed to municipalities in some cases organized in multimunicipal associations for that purpose. MSW generated at the city of Porto is collected by the municipal services also responsible for its transport to the treatment units from LIPOR, a company participated by 8 municipalities of Porto region. Due to legislative evolution, some changes have been implemented on MSW management practices since 1990. This study presents MSW production and management practices, namely collection systems and treatment units description, both on 1990 and 2000. The environmental impact from the management of MSW collected during 1 year, respectively in 1990 and 2000, is compared in terms of energy consumption and greenhouse gases emissions. This evaluation is done in two steps; first, the model developed by White et al from Procter and Gamble (5) was used to quantify energy and emissions of carbon dioxide, methane and nitrous oxide, all gases with greenhouse effect; next, the greenhouse gases emissions were aggregated using the Global Warming Potentials (GWP) proposed by the Intergovernmental Panel on Climate Change (6). This aggregation leads to a single value for the GWP of each situation analyzed, allowing its comparison. All the parameters used on this study are presented in Annex.

MSW PRODUCTION AND MANAGEMENT IN PORTO ON 1990 AND 2000

On 1990, Porto had 302 500 inhabitants and the mean MSW production was 383 kg/person.year. On that time MSW was collected 6 times a week from kerbside where people put the plastic bags with mixed waste or alternatively on containers near home. The total amount collected by this way accounted for about 115 000 tons on that year. There were also 364 glass banks spreaded on the city where people could bring used glass bottles later transported to a recycling unit. On 1990 collected glass amounted for 1 050 ton. The treatment methods available on 1990 include composting, landfilling and recycling the glass. About 70% of the mixed waste collected was composted and 30% directly landfilled. For calculation purposes, it was assumed that the fuel consumption on the collection operations was 30 L/1000 properties served and that the landfill site was similar to a dump, with neither gas collection nor lined. The fuel consumption for waste spreading operations was considered 0.6 L/ton of waste. Despite its poor quality all the compost produced at the composting unit was marketed and the residual waste from sorting operations was placed on the landfill located 100 m from the composting unit.

On 2000 the situation was quite different from that on 1990, since the inhabitants were 280 000 and MSW production was on average 518 kg/person.year. The collection systems include mixed waste collection on kerbside or from containers 6 times a week, kerbside collection of dry recyclables (paper/cardboard and plastic and metal packaging) and 2 types of voluntary bring systems, respectively central collection sites and collection banks. The dry recyclables collection was made using special plastic bags for that purpose; a yellow one for plastic and metal packaging, collected once a week, on Thursday, and a blue one for paper and paperboard, also collected once a week, on Tuesday. The bags production is also included on this study. These are made from low density polyethylene with a weight of 20g. Also for that year it was assumed that the average fuel consumption on the collection operations was 30L/1000 properties served. Collection banks include containers for packages, paper/paperboard and glass. On collection sites plastics, paper/paperboard and glass were accepted as well as other types of waste not considered on this study, for example wood and bulky wastes. A percentage of 96.4% of MSW was collected as mixed waste and only 3.6% as separate fractions from kerbside dry recyclables collection (0.6%) and bank and central sites (99.4%). The treatment methods available on 2000 for the mixed waste were composting (19.7%), incineration (79.2%) and landfilling (1.1%).

Waste fractions separately collected are transported to a central sorting unit operated by LIPOR where wastes are separated by material type and sent to recyclers. All the ultimate residues produced on this unit are lead to the incineration plant located 15 km away. The incineration plant is a mass-burn incinerator where energy is recovered producing electricity with an efficiency of 20%. There, 90% of the ferrous scrap is recovered from the bottom ash. The non-hazardous waste produced was landfilled at 15km from the incineration plant. The fly ash (hazardous waste) was transported to a landfill 300 km far from that unit during 2000. For the central sorting unit, the consumption of both 25kWh and 1L of fuel per tonne of waste was assumed. The landfill gas was collected with an efficiency of 40% and burned without energy recovery; 70% of the leachate is collected and treated accordingly. The environmental impact from that treatment is not accounted on this study. The diesel consumption for waste spreading operations was considered 0,6L/ton of waste. All the ferrous metals on the waste stream feeding the composting unit were recovered and the compost produced was marketable. The ultimate wastes from the composting unit were incinerated at the incineration plant 15 km away from the composting plant.

Table 1.: Porto waste composition on 1990 and 2000 (% by weight).

Waste component	*1990*	*2000*
Paper/paperboard	21,9	18,8
Glass	4,1	6,1
Metal	2,8	1,5
- ferrous	93% of metals	87% of metals
- non ferrous	7% of metals	13% of metals
Plastic	8,5	12,0
- film	66% of plastics	68% of plastics
- rigid	34% of plastics	32% of plastics
Textiles	3,9	2,9
Organics	35,6	36,8
Others	23,3	21,9

The waste composition in Porto had changed between 1990 and 2000. The values considered on this study are presented on Table 1 and were obtained from waste characterization procedures carried out by LIPOR (7, 8).

RESULTS AND DISCUSSION

The results of energy consumption and emissions of carbon dioxide, methane and nitrous oxide, for both the 1990 and 2000 scenarios, are summarized on Table 2. The emissions of the greenhouse gases were aggregated using the Global Warming Potentials weighting factors according to the recommendations of the Intergovernmental Panel on Climate Change (6): 1 for carbon dioxide, 21 for methane and 310 for nitrous oxide. The results obtained are also presented on Table 2.

The energy consumption for 2000 is negative due to the electrical energy recovered at the incineration process. This is a large advantage of the management system used on 2000, contrary to the 1990 one that consumes energy.

Table 2.: Energy consumption and greenhouse gases emissions from the MSW management in Porto on 1990 and 2000.

Parameter	*1990*	*2000*
Energy consumption (GJ)	58 446	-407 659
Air emissions (kg):		
CO_2	2,16E+07	1,14E+08
CH_4	5,11E+06	5,44E+04
N_2O	2,64E+01	- 3,69E+03
Global Warming Potential (kg CO_2-eq.)	1,29E+08	1,14E+08

In terms of greenhouse gases emissions the 2000 situation is worse than in 1990 in the case of carbon dioxide and better in terms of methane and nitrous oxide emissions. In 2000, the negative value for the nitrous oxide emission is due to the emissions avoided by producing electricity by a conventional power plant. Thus, it represents not only a saving of energy but also reducing the emissions associated with its production. When the greenhouse gases emissions are aggregated using the global warming potentials the results show a small advantage on the 2000 management system. However, expressing the results in 1990 and 2000 either by person or ton of waste, as in Figures 1 and 2, one concludes that global warming potential decreased less than 5% when expressed by person and 30% when expressed by ton of waste.

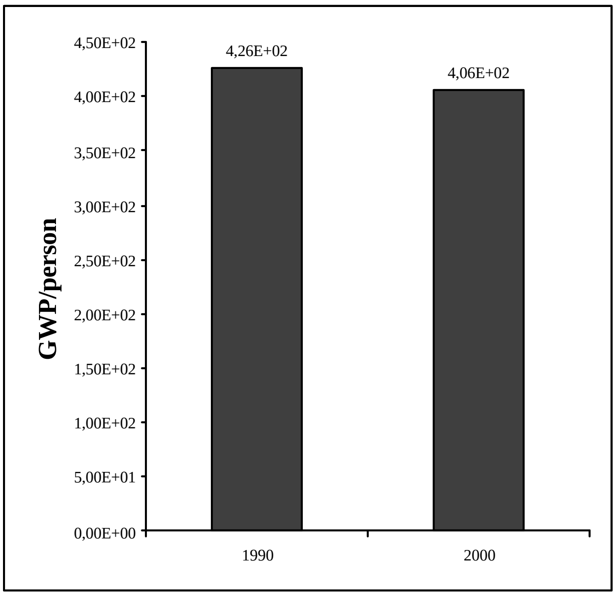

Figure 1.: Annual contribution to GWP by person from waste management practices in Porto on 1990 and 2000.

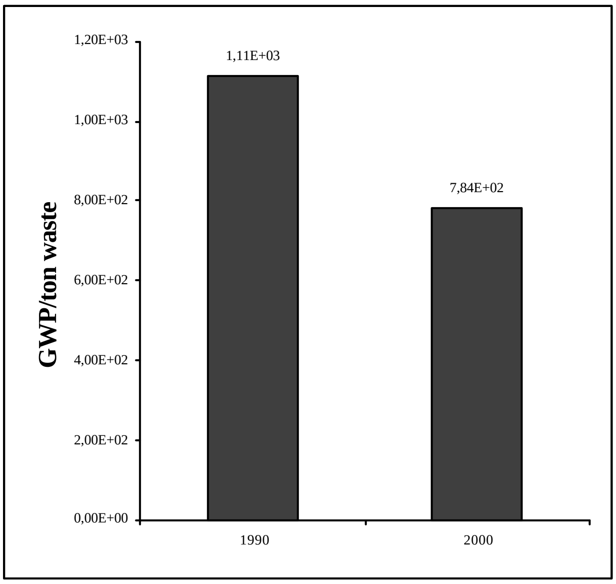

Figure 2.: Annual contribution to GWP by ton of waste from waste management practices in Porto on 1990 and 2000

CONCLUSIONS

Some changes on MSW management practices have been implemented in the municipality of Porto from 1990 to 2000 both in terms of collection systems and technologies of treatment. In terms of collection, the situation changed from mixed waste collection plus voluntary bring systems for glass to more participated solutions as kerbside collection of dry recyclables on special plastic bags twice a week, collection banks and central collection sites. Concerning the treatment methods available, the main changes include a central sorting unit and an incineration plant. The energy consumption and emissions of gases with greenhouse effect for both those years were computed using an existing inventory model.

As far as energy consumption is concerned, the results obtained show a clear advantage of the 2000 management system due to the energy recovered at the incineration plant.

For the global warming potential, results also show a clear advantage for 2000, particularly when GWP values are expressed either by person or by ton of waste, due to the decrease verified on the inhabitants of the city and the increase on the waste amount produced per person.

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Annex

Parameters from the model used

(values expressed by ton is related to ton of wastes)

Landfill

Landfill gas volume produced by wastes (Nm^3):

Paper = 250
Glass = 0
Ferrous metals = 0
Non-ferrous metals = 0
Plastic-film = 0
Plastic-rigid = 0
Textiles = 250
Organics = 250
Others = 0
Compost = 100
Bottom ash = 0

Landfill gas composition (g/Nm^3):

CO_2 = 883,93
CH_4 = 392,86
N_2O = 0

Flare exhaust gas (g/Nm^3):

CO_2 = 1964,29
CH_4 = 0
N_2O = 0

Incineration

Filter dust production = 0,032 ton/ton

Bottom ash production by wastes (ton/ton):

Paper = 0,084
Glass = 0,9
Ferrous metals = 0,85
Non-ferrous metals = 0,9
Plastic-film = 0,09
Plastic-rigid = 0,06
Textiles = 0,075
Organics = 0,077
Others = 0,42

Electricity consumption = 70 kWh/ton

Natural gas consumption = 0,23 m^3/ton

CH_4 emission= 0 g/ton

N_2O emission = 0 g/ton

CO_2 emission by waste (g/ton):

Paper = 1128500
Glass = 0
Ferrous metals = 0
Non-ferrous metals = 0
Plastic-film = 2336700
Plastic-rigid = 2492500
Textiles = 1209200
Organics = 563900
Others = 1025900

Composting

Fraction of paper and organics removed as residue during the pre-sort = 5%

Compost production = 0,5 ton/ton

CO_2 emission = 320 kg/ton

CH_4 emission = 0 g/ton

N_2O emission = 0 g/ton

Fuel, electricity, raw materials and transport

Diesel production and use:

Non-hazardous waste = 0,0057 ton/1000l
Energy consumption = 44,1 GJ/1000l
CO_2 emission = 3036258 g/1000l
N_2O emission = 41 g/1000l
CH_4 emission = 0

Polyethylene production:

Non-hazardous waste = 0,0885 ton/ton
Energy consumption = 98,1 GJ/ton
CO_2 emission = 1691657 g/ton
N_2O emission = 70 g/ton
CH_4 emission = 0

Electricity production and use:

Non-hazardous waste = 0,0491 ton/MWh
Energy consumption = 9,5 GJ/MWh
CO_2 emission = 441657 g/MWh
N_2O emission = 70 g/MWh
CH_4 emission = 0

Natural gas production and use:

CO_2 emission = 2061211 g/1000m^3
CH_4 emission = 0

Diesel consumption of a 20ton truck = 0,321l/km

Savings from ferrous metals recovery:

Energy consumption = 12,4 GJ/ton
CO_2 emission = 0
N_2O emission = 176 g/ton
CH_4 emission = 0