

EMISSION OF GREENHOUSE GASES FROM ANAEROBIC DIGESTION PROCESSES: COMPARISON WITH OTHER MSW TREATMENTS

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ABSTRACT

This contribution analyzes the anaerobic digestion process and compares emissions estimated for four different management processes for MSW (Municipal Solid Waste): biogasification, landfilling, composting and incineration. The comparison has been undertaken by considering in the estimation of the emissions the full cycle of MSW treatment, and not only the emissions derived from the fraction of MSW treated by each particular system. For instance, the fraction of MSW not submitted to biological treatment has to be incinerated or deposited in a landfill. The corresponding emissions of these processes have to be considered in the calculations of the final emissions.

KEYWORDS

Biogasification; composting; incineration; landfill; greenhouse gases emissions; emission factors.

INTRODUCTION: CLIMATE CHANGE

Climate change is widely recognized as one of the bigger and more serious potential threats to the environment. The problem is being addressed through the United Nations Framework Convention on Climate Change (UNFCCC), most recently at the third Conference of the Parties at Kyoto in December 1997. It has been identified by the European Union (EU) as one of the key environmental issues to be tackled under the Fifth Environmental Action Program.

Climate is strongly influenced by changes in the atmospheric concentrations of certain gases that trap infrared radiation from the Earth (the "greenhouse effect"). Water vapor and carbon dioxide (CO₂) in the atmosphere produce a natural greenhouse effect, without which the Earth's surface would be about 33° C colder than it currently is (IPCC, 1990). Other important greenhouse gases (GHG) are methane (CH₄), nitrous oxide (N₂O), and halogenated compounds such as CFCs and perfluorocarbons (PFCs).

Over the last century human activities have led to increases in the concentrations of greenhouse gases and other pollutants in the atmosphere. A large increase, in historic terms, in global mean temperature has also been observed over the same period. Although it is uncertain how much of this warming can be attributed to greenhouse gases, there is evidence that human activities are causing an enhanced greenhouse effect or global warming (IPCC 1996). Fossil fuel burning is the dominant driving force of the enhanced greenhouse effect. Other activities that contribute are agriculture and land-use changes

including deforestation, certain industrial processes such as cement production, waste management systems, and refrigeration, foam blowing and solvent use.

Climate change resulting from the enhanced greenhouse effect is expected to have widespread consequences, causing: sea-level rise and possible flooding of low-living areas; melting of glaciers and sea ice; changes in rainfall patterns with implications for floods and droughts; and changes in the incidence of climatic extremes, especially high-temperature extremes. These effects of climate change could have impacts on ecosystems, health, water resources, and key economic sectors such as agriculture, and water resources.

While the extent of climate change that could be regarded as sustainable is uncertain, the overall conclusions generally support the view that policy action to curb greenhouse gas emissions and control global warming is essential. It is also recognized that it is important to identify the extent to which the harmful consequences of climate change could be minimized by adaptation. The timing of policy action is a key issue, because there is a large time delay between a reduction of the emission of greenhouse gases and stabilization of atmospheric concentrations.

Table 1 shows different estimates of the contribution of the different GHG to global warming and the contribution of different sources to methane emissions. As can be observed, methane is estimated to contribute between an 18-20% to the radiative forcing that increases the natural greenhouse effect. About an 11% of this contribution is due to the disposal of MSW in landfills.

TABLE 1 CONTRIBUTION OF THE DIFFERENT GHG AND DIFFERENT SOURCES OF METHANE EMISSIONS.

Contribution of the different greenhouse gases (%)	IPCC (1996)	USEPA (1993)
CO ₂	65	66
CH ₄	20	18
CFCs	10	11
N ₂ O	5	5
Contribution of different sources to methane emission	IPCC (1994)	IPCC (1992)
Energy production	26	28
Enteric fermentation	24	23
Rice cultivation	17	21
Wastes	7	17
Landfill	11	
Biomass burning	8	11
Urban wastewater	7	

IPCC: Intergovernmental Panel on Climate Change

A correct Municipal Solid Waste management system should consider an integrated management of the different available alternatives and be directed towards a better conservation of the resources. To evaluate the potential environmental impact of the different possibilities for MSW treatment, decision-makers should take into account not only their local or regional effects, but also their global consequences as sources of greenhouse gases.

MSW TREATMENTS AND EMISSIONS OF GHG

Disposal and treatment of municipal wastes produce emissions of greenhouse gases, especially CH₄ and CO₂. The different possibilities for municipal solid waste treatment are described below.

Biogasification: In the absence of oxygen, anaerobic microorganisms ferment the biodegradable organic fraction of the MSW, which results in an effluent liquid or semi-liquid. In the biogasification treatment this process takes places at higher speeds to that of other more classic treatments such as composting. The process releases a gas constituted fundamentally by CO₂ and CH₄, as well as traces of volatile organic compounds (VOCs). The resulting liquid or semi-liquid contains pathogen microorganisms (although the process takes place at mesophilic temperatures), has a relatively poor fertilizing value and high humidity content. It must be submitted to a second aerobic digestion process, to obtain compost. Therefore, it is necessary to combine biogasification with aerobic stabilization for the complete digestion of the waste. It produces a net energy of 100 to 150 kWh per tone. This is a relatively new MSW treatment process since its operational development has little more than ten years.

Landfilling: Landfilling of MSW represents the most extended system of MSW disposal in the world. In addition to CH₄, landfills can also produce important amounts of CO₂ and non-methane VOCs (NMVOCs). Control and recuperation of the landfill biogas did not begin in the United States until the end of the 60's and beginning of the 70's, when gigantic landfills were created. The first landfill facility with biogas control in Europe was install in Germany in the mid 70's, incorporating quite of the experiences acquired in the US. Thereinafter it was extended all over Europe and other countries.

Composting: Composting the fermentable organic fraction of MSW produces a reusable product. In the presence of oxygen, microorganisms decompose the biodegradable organic matter in a material named compost, which contains nutrients and oligo-elements, and is used in agriculture as soil conditioner. The composting process emits a gas basically formed by carbon dioxide (CO₂) and water (H₂O), while traces of volatile organic compounds (VOCs) are also present. These last compounds are responsible for the characteristic odour of this type of facilities. Composting plants consume between 30-35 kWh of energy per tone of waste treated.

Incineration: Waste incineration, like all combustion processes, can produce CO₂, CO, NO_x and NMVOCs. Municipal waste incineration reduces its volume and allows energy recovering either for heating or electricity generation.

EMISION FACTORS

Emission factors have been estimated for the different MSW treatments described above. However, calculations have been carried out taking into account the following premises:

1. They have been estimated from the elemental content of MSW. This elemental content has been calculated from the typical composition of MSW in Barcelona (Spain), which is shown in table 2.

TABLE 2 ELEMENTAL CONTENT OF BARCELONA'S MSW.

Percentage distribution	%
C	46.12
H	5.96
O	31.62
N	0.83
S	0.13
Ashes	15.34

2. We have formulated the complete combustion and fermentation processes that take place in each treatment. Only the corresponding fraction for each treatment has been considered. For instance, only 63.5% of total MSW can follow a biological treatment, while 86.9 % can be incinerated.

3. The whole MSW management system has been considered, which meant that in some cases the complete MSW treatment involved the combination of different processes. For instance, the non-fermentable fraction of a biological system has to be incinerated or disposed in a landfill. The MSW systems considered have been:
- Landfill
 - Incineration
 - Sorting + Composting + Landfill
 - Sorting + Composting + Incineration
 - Sorting + Dry Biogasification + Landfill
 - Sorting + Wet Biogasification + Incineration + Landfill
4. In estimating the contribution of the methane gas to the greenhouse effect one should consider both the amount of the emissions and its Global Warming Potential (GWP). The GWP is an index of the relative greenhouse effect of a given molecule (methane in this case), with respect to that of CO₂, which is used as a reference. Using the GWP, CH₄ emissions have been transformed into equivalent CO₂ emissions.

The resulting estimated emission factors are shown in Table 3.

TABLE 3 EMISSION FACTORS FOR DIFFERENT MSW MANAGEMENT SYSTEMS.

MSW Treatment	Emission Factor (t eq. CO ₂ /t MSW)
Landfill	1.97
Incineration	1.67
Sorting + Composting + Landfill	1.61
Sorting + Composting + Incineration	1.41
Sorting + Dry Biogasification + Landfill	1.42
Sorting + Wet Biogasification + Incineration + Landfill	1.19

In the use of these emission factors for GHG emission inventories, one should take into account that CO₂ released in these processes is generated from the fermentable fraction of organic material derived from biomass sources (e.g. crops, forests). Since this biomass is re-grown on an annual basis, these CO₂ emissions should not be treated as net emissions from waste according to the IPCC methodology and guidelines to develop emission inventories of GHG (IPCC, 1995). If biomass raw materials are not being sustainably produced, net CO₂ emission should be taken into account in the emission inventory.

CONCLUSIONS

GHG emissions factors for different MSW treatment systems have been calculated taking as basis the elemental content of typical MSW in Barcelona, Spain. This study has shown that reduction of GHG emissions must be accounted through an integrated MSW management system combining different treatments, as opposed to the use of one single process. A combination approach is the best way to extract the material and energetic recycling potential of the different fractions of MSW.

REFERENCES

- IPCC (1990) *Climate Change, The IPCC Scientific Assessment*. WMO, UNEP.
- IPCC (1995) *IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. I, II and III. UNEP-OCDE-IPCC.
- IPCC (1996) *Second Assessment Climate Change 1995, A Report of the Intergovernmental Panel on Climate Change*. WMO, UNEP.