Environmental effects of landfilling of solid waste compared to other options – assumptions and boundaries in life cycle assessment.

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Introduction

In many countries, both energy systems and waste management systems are changing. One driving force for these changes is the threat of climate change caused by emissions of CO_2 and other greenhouse gases. In discussions on waste management, a waste hierarchy is often suggested. Although different hierarchies are suggested a common feature is that recycling of waste is preferable over incineration which is preferable over landfilling. In this study we have compared different treatment options for the combustible and recyclable fractions of municipal solid waste. The aim has been to identify advantages and disadvantages of different treatment methods and also to test the validity of the waste hierarchy.

Methods

For the study we have used Life Cycle Assessment (LCA) methodology. Established methods have been used for both the Life Cycle Inventory Analysis and for the Characterisation. Weighting is performed using two different weighting methods.

The study is based mainly on Swedish conditions. In the base scenario of the study, the assumptions made are that marginal electricity is produced from hard coal, avoided heat production is from forest residues, transports are short and the time perspective is the hypothetical infinite. Gas collected from landfills are used for heat and electricity generation, and 50% of the landfill gas is assumed to be collected. Many of these assumptions are altered in different scenarios to test the influence of varying conditions.

Results

With the assumptions of the base scenario the waste hierarchy is found to be valid for the impact categories total energy, greenhouse effect, photochemical oxidant formation, acidification, eutrophication, sulphur oxides, human toxicology and for total weighted results. For other impact categories, slightly different results are obtained. Considering non-renewable energy, abiotic resources and nitrogen oxides the ranking shows recycling to be preferred before landfilling, leaving incineration to be the least preferred alternative. The ecotoxicological impact category gives different rankings depending on which characterisation and weighting methods that are used. Different rankings within an impact category may also be found for separate fractions of the household waste.

A major reason for landfilling being ranked low is often that recycling and incineration with heat recovery produce products, either recycled material or heat, which can substitute other products. From landfilling, some landfill gas is collected, but in general less products are received.

In the study performed different scenarios have subsequently been analysed, altering some of the assumptions of the base scenario. Most relevant from a landfilling perspective are time aspects, application of the carbon sink concept and transportation issues.

Time perspective
Emissions from landfills, as opposed to those from incineration and recycling processes, are very much spread over time. When modelling a landfill different time perspectives may give rise to different results. In the base scenario a hypothetical infinite time perspective is used. This time perspective is defined by a complete degradation and spreading of all landfilled material. We have also studied a shorter time period, called the surveyable time period, corresponding to approximately 100 years. When a shorter time period is used, landfilling appear as a more attractive option. Emissions of metals are reduced as well as emissions of carbon from landfilled plastics. This leads to changed rankings of waste management options for plastics regarding greenhouse gases, where landfilling becomes the second best option and for the whole system for the category ecotoxicological impacts, where landfilling is credited differently depending on impact assessment methods used.

Carbon sink
With the shorter time perspective described above there is also a possibility to consider the landfill to be a carbon sink. This assumptions applies to the part of the waste containing biological carbon, which is not degraded and released to the atmosphere during the surveyable time period. This carbon stays in the landfill, and may therefore be considered to be withdrawn from the atmosphere. Applying this concept, the amount of biological carbon withdrawn may be credited the landfill option as avoided CO_2 emissions. In the study, this assumption leads to a result where the ranking of the different options are altered for the impact category greenhouse effect, which also makes out a large part of the total weighted impacts. The ranking becomes recycling preferable to landfilling, which in turn is preferable to incineration for the total weighted values and also, with a small difference between the last two, for the greenhouse effect category.

Transportation of waste
When comparing different waste management options it is also of interest to consider differences in transportation demand between them. In the cases of recycling and sometimes also incineration, the waste has to be separated into fractions and transported by households to collection points. Distances to them and from them to the processing facilities are compared to the distances to the landfills. In the study performed it can be seen that the transportation to processing facilities by highway trucks are not making any major influence on the results. Transport by passenger car may however give a significant impact in some categories, mainly for photochemical oxidant formation, sulphur oxides and toxicological aspects. The assumption that no transportation by passenger car is made for landfilling, thus favours this option.

Conclusions
Depending on the way landfills are modelled and on the assumptions made for the system under study, life cycle assessments may in some cases give results where landfilling is preferred to incineration. In general, the most preferable option is recycling. It is important to get more certain ways of modelling and assessing waste management options to be able to get more reliable results.