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Present and Future Strategies for Biowaste Management

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Abstract
Based on the waste hierarchy, biological treatment of biowaste is propagated EU-wide as the best option for management of biowaste. Dutch municipalities have the obligation to separately collect biowaste at source since 1993. Since then, the amount of source separated organic waste has increased rapidly and is now more or less stable at 1.5 million ton per year, corresponding to 50 % of the biowaste that is generated by households. On the other hand, the life cycle analysis supporting the Dutch National Waste Management Plan 2002-2012 concluded that biological treatment of source separation and biological treatment of biowaste has no beneficial environmental effects compared to incineration of integral household waste. As the costs for source separated biowaste management are still more favorable it is expected that the level of source separation and biological treatment of biowaste will be stable in coming years. The Dutch situation shows the importance of other aspects than environmental issues only when it comes to the selection of the most viable biowaste management strategy. These aspects are among others product properties, competition on the market, flexibility of the process, the impact of regulations and costs. This paper presents an innovative decentralized treatment of biowaste in which the indoor fraction and outdoor fractions of biowaste are separately treated on-site by decentralized sanitation and home-composting, respectively. This strategy for biowaste management appears to be more sustainable and certainly more cost-effective. It is advised that this novel biowaste management strategy will be considered for evaluation in future LCA studies.

1 Biowaste management in the Netherlands
1.1 Definition
Biowaste is the organic fraction of municipal solid waste. In this paper, the term

'biowaste' is only used when this fraction is separately collected at source (i.e. households) before being introduced into the waste management chain. Biowaste from households consists of indoor and outdoor organic waste. In the Netherlands about 35 % (by mass) of household waste is composed of biowaste. Less biowaste will be generated in high-rise buildings (no garden) compared to low-rise residences (with garden). Indoor biowaste is mainly composed of food remains and small amounts of plant remains. Constituents of outdoor biowaste are grass and tree cuttings, leaves, dead plants and flowers and a surprisingly high fraction of soil particles (Veeken, 2005). Due to the presence of relatively high amounts of soil, a large part of biowaste is of an inorganic nature (sand and other soil minerals). Moreover, the organic matter introduced with the soil fraction (humus) is very stable as compared to the other organic materials in biowaste.

1.2 Waste hierarchy and integrated waste management

Currently, the so-called 'waste hierarchy' is widely accepted as the preferred order of waste management options. This order is: prevention, re-use, recycling, incineration (with energy recovery) and landfilling. In the Netherlands, as well as in the European Union, the waste hierarchy is the norm to evaluate waste management programs; it is also implemented in national legislation. A strong point of the waste hierarchy paradigm is that it provides a very robust and straightforward principle but the limitations of this paradigm become increasingly clear and call for adaptations. The waste hierarchy considers only environmental objectives without considering other objectives. Moreover, the waste hierarchy contains waste management options (e.g. prevention, reuse) which are solution neutral on the one hand, but contain working principles on the other hand. These limitations indicate that the waste hierarchy paradigm is an unsatisfactory tool for decision making and for specific designing processes because it does not allow for selection of a specific technology for a specific case (Hamelers et al., 2005). Environmental management tools such as Life Cycle Analysis (LCA) and Cost Benefit Analysis (CBA) can help to evaluate waste management strategies with respect to both environmental and cost effects. Integrated waste management aims at an overall waste management system that result in the most effective system in both environmental and economic terms and which is socially acceptable at the same time.

Since 1993 Dutch municipalities have the obligation to separately collect biowaste at source with the exemptions of highly populated urban areas where production rates of biowaste per household are below average and temporary storage by households leads to unfavorable conditions and rural areas where the ratio between collected amount of waste and collection costs is relative low. The amount of source separated organic waste has increased rapidly since the mid nineties and is now more or less stable at approx. 1.5 million ton per year, corresponding to a recycling rate of 50 %. In 2005 the Ministry of Housing, Spatial Planning and the Environment announced a new set of exemption rules that gen-

erally gives more freedom to municipalities to establish their own policy for the collection of biowaste. However, as the costs of waste management options for source separated biowaste currently are favorable it is expected that the level of source separation will be stable in coming years.

2 Options for biowaste management

2.1 Prevention and reuse

As always, prevention is the best option to reduce waste-related environmental problems and that is true also for biowaste. Prevention also reduces the costs of biowaste management as the amount of waste that has to be collected and treated is reduced. However, is prevention a realistic option in our modern European? The constituents of biowaste that can possibly be reduced by direct prevention are food remains and top soil. Food remains can be reduced by being more efficient in food consumption. As our society evolves to a throw-away society and the trend is towards smaller households, it is however expected that the amount of indoor biowaste will even increase further. Although instruction folders instruct not to collect top soil with outdoor biowaste, people do not act on this information. A viable solution could be to introduce a weight-based collection scheme for biowaste (pay-as-you-throw) as has been successfully implemented for residual waste in the Netherlands.

Indirect prevention of biowaste is possible by treating the biowaste at home by composting. In this way, biowaste is turned into compost that can be used in the garden. Evidently this option is only applicable in rural areas and specific urban areas where most houses have gardens. Home-composting will thus not be possible in highly urbanized areas with mainly flats and apartment buildings. As for direct prevention, the costs are significantly reduced by home-composting as the amount of biowaste that has to collected and treated is reduced. This option needs the willingness of people to cooperate but can be stimulated by public campaign and awareness programs. While participation in home-composting is very low in the Netherlands, home composting of biowaste is done by 35 % of the households in Flanders, Belgium as a result of active campaigns and public awareness programs.

2.2 Recycling

Direct re-use of food remains and garden waste as organic fertilizer for agriculture/horticulture is not allowed by law as this will result in environmental pollution and damage to the crops. Therefore, biowaste can only be returned to the soil as compost after sanitation and stabilization of organic matter. Biowaste can be recycled by composting or digestion and the resulting product can be applied as soil improver (organic fertilizer) in various areas such as agriculture, horticulture and landscaping. Composting will result in recycling of nutrients and the stabilized organic matter is beneficial to the soil. By anaerobic digestion part of organic

matter can be transformed into biogas, a renewable energy source composed of approx. 65 % methane and 35 % carbon dioxide. Risks associated with compost are the presence of contaminants such as heavy metals. Therefore strict standards for compost usage were laid down in the Netherlands' law that are even stricter than current EU standards (Veeken, 2005).

2.3 Incineration with energy recovery

Incineration of biowaste itself does not gain energy. On average (assuming total solids content of 50 % and volatile solids content of 50 %) the calorific value of biowaste is about 3 MJ/kg, which is not enough to result in net energy production by incineration. Only other dry organic components of household waste like plastics and paper will result in energy recovery from household waste components. As biowaste is largely made up of inorganic constituents, about 50 % of the dry solids will end up in incineration ashes. It therefore sounds logic to divert biowaste from incineration plants as in this way more capacity is made available for wastes with a higher calorific value. Moreover, removing biowaste from residual waste gives way to the construction of incinerators for high-calorific wastes that have higher energy recovery efficiencies.

2.4 Landfilling

Landfilling of biowaste will result in greenhouse gas emissions (methane) and pollution of soil and surface and groundwater via leachate production. The environmental effects can partly be reduced by landfill gas extraction and well-designed bottom liner and leachate treatment. However, these measures are not fully adequate and therefore several EU countries have banned landfilling of biowaste. According to the EU Landfill directive it is targeted to reduce landfilling of biodegradable waste by 75 % in 2012.

2.5 Current status

Currently some 97 % of source separated biowaste is treated in composting facilities. The remaining fraction of biowaste is treated in a facility for anaerobic digestion. The current composting facilities for biowaste are mainly closed systems providing proper means of process control. These plants produce about 0.5 million ton of compost which is of high quality. However, due to market competition with animal manure and strict environmental regulations, it may still be difficult to sell the compost as a soil improver in Dutch agriculture. That is why new outlets for compost are growing. For instance, compost is used as a peat replacement in potting soil up to a maximum content of 20 % in the total potting soil mixture. Other technologies such as pyrolysis and gasification have been explored but this has not yet led to operational facilities. Next to this, the current discussion is focusing on the future use of biowaste as biomass for heat production or for the production of green chemicals.

As about 50 % of biowaste is source separated, the other half is collected as

integrated municipal solid waste. The common waste management option for integrated municipal solid waste in the Netherlands is incineration. A small fraction still enters a landfill as biological stabilized waste but this practice will end in a few years.

3 Dutch LCA experiences with Biowaste Management

3.1 Introduction

The use of LCA in the field of waste management started of with the first developments in LCA methodology and its applications. Since the mid 90's numerous waste related studies have been conducted and published in reports and international journals. The Dutch National Waste Management Plan 2002-2012 (NWMP) that came into action in March 2003 was supported by more than 150 LCA studies for well over 20 types of industrial and municipal waste. In particular the results of the LCA study for biowaste have been subject of debate. Several additional studies have been dedicated to this topic and have led to a sound overview of relevant parameters, knowledge gaps and uncertainties. Here we will highlight the status of Dutch LCA knowledge related to biowaste management. The knowledge can be useful since the international discussion about this topic is far from over as the current Landfill Directive, and in the future possibly a Biowaste Directive, remain strong incentives for national policy developments in this field.

3.2 Life Cycle Assessment of Biowaste Management Options

The life cycle inventory for the composting of biowaste is based on an expanded LCA-system. In this system the use of process outputs (products and secondary materials) leads to a bonus as avoided primary products can be taken into account. With this approach allocation can be avoided as favored by ISO14040. Indeed many tools for waste management take into account the benefits of products and secondary materials. In case of composting this is translated into decreased use of chemical fertilizers, animal manure and peat.

The functional unit of the LCA-system has been defined as the management of 1 ton of biowaste as collected at households by municipalities. The LCA-system starts with the transport of biowaste to the composting facility and ends with the use of products and secondary materials. All upstream processes within this system are taken into account. The inventory is aiming at emissions to air, soil and water, as well as land use and final waste production. The results of the LCA study for the different biowaste management options that were considered in NWMP are shown in Figure 1. Gasification of biowaste, combined with generation of electricity, has the lowest environmental impact. The gasification technology however is not in practice now and not likely to become in practice soon. The highest impact is for incineration, followed by composting after separate collection. In an additional sensitivity analysis the produced energy with incineration was taken into account leading to much less environmental impact for incinera-

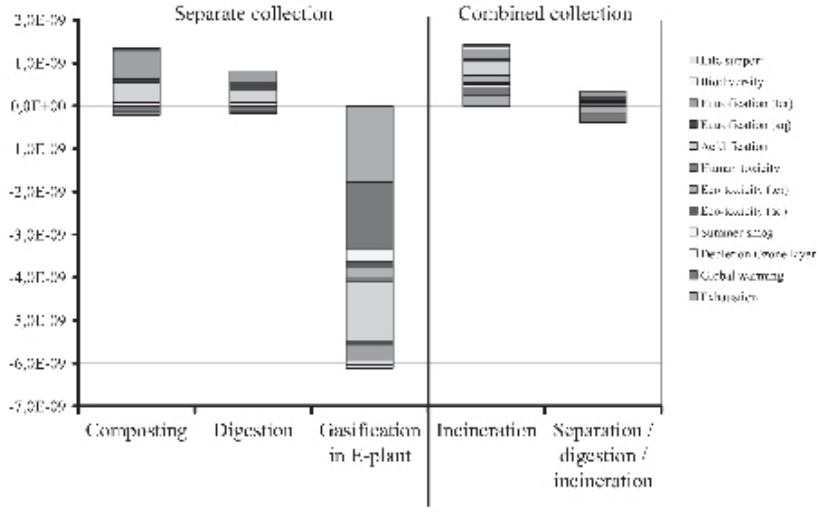


Fig. 1: Weighted normalized LCA impact scores for 5 Dutch biowaste management options (NWMP, 2002)

tion resulting in the best score after gasification.

From the LCA study (Figure 1) it was concluded that biological treatment of source separated biowaste has no beneficial environmental effects as compared to incineration. These findings are in agreement with other studies on LCA for biowaste management (Sundqvist, 2005). This first LCA study in NWMP also led to a discussion about the benefits of compost although agricultural studies show evidence that compost has a positive impact on soil quality leading to better water management, less soil erosion and improved soil fertility (Saft and Ewijk, 2006). Due to a lack of sufficient causal data such relations are difficult to quantify in LCA studies. Most recent insights on agricultural effects of the use of compost have been gathered in a recent study commissioned by the Dutch United Waste Companies (Brinkmann et al., 2004). From this study several topics relevant for the application of compost were selected: substitution of chemical fertilizers, nitrogen emissions, C-sequestration, leaching of heavy metals, disease suppression, crop yield and compost market analysis. It resulted in a new comparison between incineration and composting as shown in Figure 2. If all heavy metals in compost would be counted as a net emission to the soil, the effect of the LCA-indicator 'terrestrial ecotoxicity' becomes overall dominant. This results in a strong negative environmental profile for the separate collection/compost alternative. This environmental profile is unrealistically negative as the Netherlands has developed very strict standards for heavy metals with respect to bio-

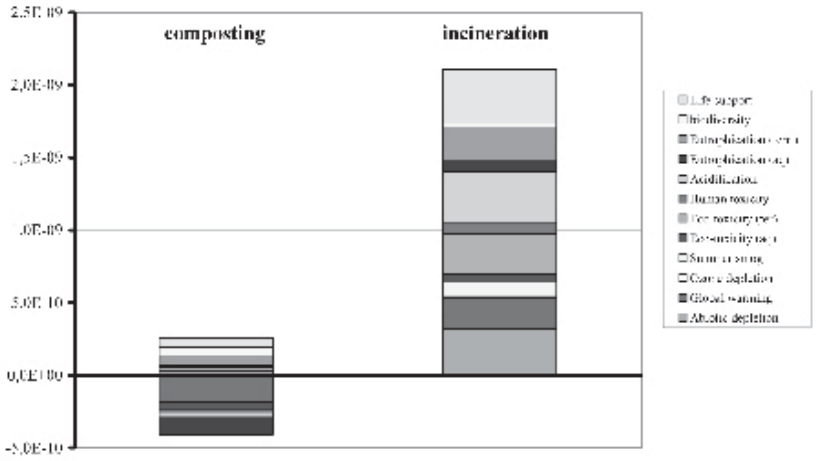


Fig. 2: Weighted normalized LCA impact scores for incineration and composting (Brinkmann et al., 2004)

waste-compost application to avoid heavy metal accumulation in soils (Veeken, 2005). It has been shown that only a very limited percentage of heavy metals in compost can potentially contribute to environmental effects. Furthermore, LCA-experts acknowledge that the LCA-methodology is weak as far as heavy metals are concerned. In the study of Brinkmann et al. (2004) a sensitivity analysis was carried out in which 10 % of all heavy metals in compost were considered as net emission, which is in line with research results on bio-availability of heavy metals in soils. The environmental profile of separate collection/composting of biowaste is mainly determined by the beneficial environmental effects of artificial fertilizer replacement. These positive effects exceed the negative impacts through emissions of ammonia (NH_3), nitrous oxide (N_2O) and methane (CH_4), as well as impacts related to biowaste transport.

The Dutch situation shows the importance of other aspects than environmental issues only when it comes to the selection of the most viable biowaste management strategy. These aspects are among others: product properties, competition on the market (dry, odor free, hygienic product), flexibility of the process, the impact of regulations and costs.

3.3 Outlook

The Dutch experiences with LCA studies for biowaste management indicate the relevance of local conditions and circumstances for the environmental profile.

Knowledge on these topics will continue to grow coming years. Some parameters have not been properly elaborated in LCA, such as the impact of compost on soil fertility, soil water management and overall increasing crop yields. For example, the improved workability of the land, resulting in less fuel consumption for tillage operations, can be properly covered with LCA. On the other hand the improved crop yield might be used as a proxy for many benefits of compost and be integrated in LCA by using system expansion. The first NWMP is evaluated in the first half of 2007 leading to recommendations for NWMP-2. Special attention is given to the use of LCA for the Environmental Impact Reporting, and thus experiences of LCA as a decision support to policy making. IVAM will participate in this evaluation.

A dynamic approach of LCA is needed in the European context, as local and regional differences are very relevant especially when we consider the application of compost. The influence of local conditions shows that a dynamic modeling is needed when (local) market conditions are taken into account. As currently LCA is mainly used as a static tool this requires sound scenario building by LCA practitioners. Given the various national initiatives on biowaste management and the increased attention for life cycling thinking such an approach can surely support policy makers. The Institute for Environment and Sustainability from the European Commission's Joint Research Centre announced early 2007 the development of "European Life Cycle Thinking Guidelines for the Management of Municipal Biodegradable Waste". This study will be conducted by IVAM, University of Amsterdam.

4 Decentralized sanitation and home composting of biowaste

In accordance with the waste hierarchy and taking into account the costs, composting is an attractive option for biowaste management. The system can still be further optimized taking into account that only 50 % of biowaste that is generated is actually source separated and collected. Another issue is the fact that 50 % of biowaste that is collected is composed of soil constituents that do not have to be treated by definition. This implies that 0.75 million tons of soil constituents in biowaste are unnecessarily transported and composted in the present situation.

From an environmental and cost perspective, treatment at the source by home-composting is an excellent alternative but has a number of constraints. First of all, home-composting can only be done by households that have a garden and not by people living in flats and apartment buildings. Secondly, as the temperature of the home-composting process cannot be controlled properly, the process can be problematic for indoor generated biowaste (especially food remains) resulting in the generation of odors, potentially harmful gaseous emissions (CH_4, N_2O, NH_3), and production of poor-quality compost of that is not properly stabilized and sanitized.

The problems of the home-composting process can be overcome if the indoor and outdoor fractions of biowaste are separately collected and treated. Outdoor

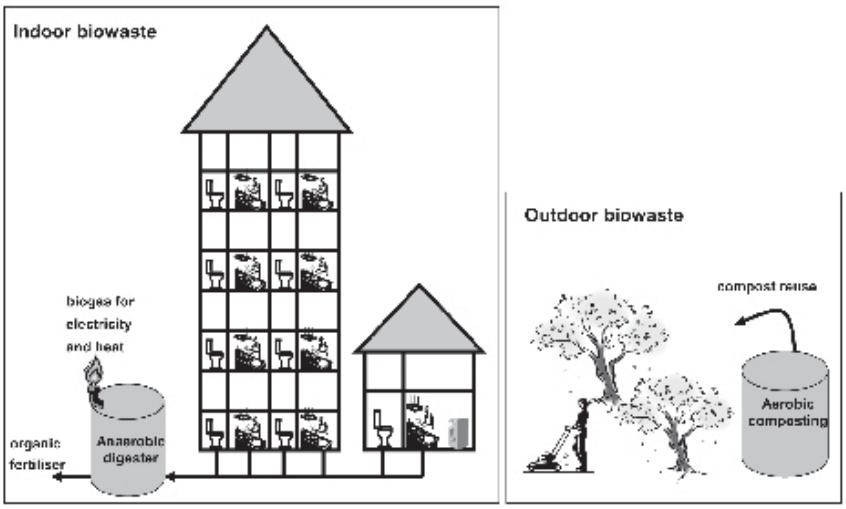


Fig. 3: Schematic presentation of separate collection and treatment of the indoor and outdoor biowaste fractions

biowaste is then processed by home-composting while indoor biowaste is treated through a decentralized sanitation approach that is currently piloted (Kujawa-Roeleveld et al., 2006). In combination with a pay-as-you–throw program for biowaste management this approach could significantly improve the source-separation and recycling rate of biowaste. This innovative biowaste management strategy is schematically presented in Figure 3.

New developments in wastewater collection systems offer solutions to remove and treat indoor biowaste together with wastes from toilets. The new approaches include the use of low-flush vacuum toilets and of vacuum sewers for removal of toilet wastes to anaerobic digestion systems (e. g. see www.desar.nl). Vacuum systems transport solids by a combination of suction and a little water to a digestion step where energy can be produced. It is possible to also use vacuum collection systems for the removal of indoor biowaste. For this purpose a food and biowaste disposer is installed in the kitchen sink. The use of kitchen disposers is widely established in the USA where the removal of indoor biowaste through grinders in the kitchen is common. The disposer is connected to the vacuum sewer and removes the biowaste to the same digester where the toilet waste is processed. Pilot-scale experiments at Wageningen University showed that approx. 50-60 m^3 biogas can be generated per household per year from toilet wastes and indoor biowaste. The residues after digestion are low in heavy metals compared to sew-

age sludge and can be applied as organic fertilizer. Recently a pilot project with 30 houses equipped with vacuum toilets has been established in the city of Sneek, The Netherlands. The toilet wastes are digested in a so-called UASB-septic tank that is located inside the area (Kujawa-Roeleveld et al., 2006). The produced biogas is used for block heating. One of these houses is also equipped with a kitchen disposer that is connected to the vacuum system.

The advantages of combined collection of toilet wastes and indoor biowaste are (1) it is a user-friendly way of indoor biowaste removal from the household that will most likely increase the collection rate (2) the home-composting of outdoor collected biowaste is significantly improved (3) indoor biowaste is used as a renewable energy source. A disadvantage is the fact that it requires a totally new infrastructure and will at present only be attractive for newly built housing districts and flat buildings.

Centralized and separate treatment of the indoor and outdoor fractions biowaste appears to be a more sustainable biowaste management strategy compared to the present strategies and should be considered in future LCA studies.

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