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Life cycle assessment of two biowaste management systems for Barcelona, Spain

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Abstract

A life cycle assessment (LCA) is performed in this study in order to evaluate the environmental implications of the management of the fermentable fraction of waste in the Barcelona Metropolitan Area (BMA), comparing the present management system with the system proposed for the future. The energy and water consumption were quantified, as well as the used area and the emissions to the atmosphere and water. The software TRACI was used in order to assess the potential impact on the categories of acidification, eutrophication, toxicity and harm to the human health (under the criteria of cancer, non-cancer and pollutants), global warming, depletion of the ozone layer, formation of photochemical smog, water use, land use and fossil fuel use. The results show that the management system proposed for the future reduces 7 out of the 12 potential impacts analyzed, due mainly to the change in the technology of landfill (baling-wrapping landfill). However, this system requires of further research to assess the impacts on a long term. The worst option for biowaste management is the traditional landfill, based on the multibarrier concept. The results of this work suggest that the future biowaste management system is better in environmental terms than the present system.

Keywords: Life cycle assessment; Biowaste; Barcelona waste management; Compost; Biogasification; Incineration; Landfill; Baling-wrapping landfilling

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1. Introduction

The search for sustainable development demands the reduction in the production of waste, as well as the generation of new management strategies that minimize the environmental impacts. Because of that, it is necessary to assess in an objective way the environmental implications derived from the waste management systems.

The life cycle assessment (LCA) is an objective and systematic tool, which has been applied to the evaluation of municipal waste (Barlaz et al., 1995; Barton et al., 1996; Bjorklund et al., 1999; Finnveden, 1999; Finnveden et al., 1995; McDougall et al., 2001; Mendes et al., 2003; Sonesson et al., 2000; Turkulainen and Katajajuuri, 2000; White et al., 1995, among others).

The LCA studies the environmental aspects and the potential impacts through the life of a product or service, from the extraction of raw materials, the production, the use and the final disposal. That means, developing an inventory of relevant inputs and outputs of the system (inventory analysis), assessing their potential impacts (impact assessment) and interpreting the results in relation with the proposed targets (interpretation).

In this paper, a LCA is developed for assessing the environmental implications of the biowaste management in the Barcelona Metropolitan Area (BMA), comparing the actual management system (using data from the year 2002) with the proposed system for the future. In the last case we use the information proposed for the year 2006 in the Metropolitan Program for the Management of Municipal Waste (PMGRM) (AMR, 1997).

2. Methodology

The BMA is formed by 33 municipalities of the Barcelona province, covers an area of 585 km^2 and has a population of 2,927,721 inhabitants. During year 2002, the fermentable fraction of waste, also called biowaste, added up to 582,669 t (AMR, 2003). It constitutes the functional unit for this work.

2.1. Boundaries of the systems

For a better understanding of the sources of environmental impacts, the systems have been divided in the processes described in Table 1.

Figs. 1 and 2, for actual and future biowaste management systems respectively, depict the processes analyzed. In both cases the systems includes the cycle from collection to the final disposal of biowaste in final treatments. The approach of the expanded boundaries proposed by Finnveden (1999) is adopted, and the compensatory processes of electrical power generation and compost production are included for making both management strategies comparable.

2.2. Description of the systems

2.2.1. Collection of biowaste

In the actual system, the collection of biowaste was carried out according to the following percentages: CO-SE 13%, CO-PE 9% and CO-NS 78%. For year 2006, the projections are: CO-SE 78% and CO-NS 22%.

Table 1
Processes taking part in the management systems analyzed

Process	Description	Actual biowaste management system	Future biowaste management system
CO-SE	Selective collection	√	√
CO-NS	Non-selective collection	√	√
CO-PE	Outlying (private) collection	√	
COM-S	Composting with material from selective collection	√	√
COM-P	Composting with material from outlying collection	√	
COM-B	Composting with the remainder material from biogasification		√
BIO	Biogasification	√	√
BWT	Biogasification wastewater treatment	√	√
INC	Incineration	√	√
TS	Transfer station	√	
T-TSL	Transport from transfer station to sanitary landfill	√	
T-SEL	Transport of compost refuse, from selective collection composting facilities to sanitary landfill	√	√
T-PEL	Transport of compost refuse from private composting facilities to sanitary landfill	√	
T-BIL	Transport of biogasification refuse to sanitary landfill	√	√
T-BIN	Transport of biogasification refuse to incineration facilities		√
LAN	Sanitary landfill	√	√

The symbol √ indicates the presence of this process in the management system indicated.

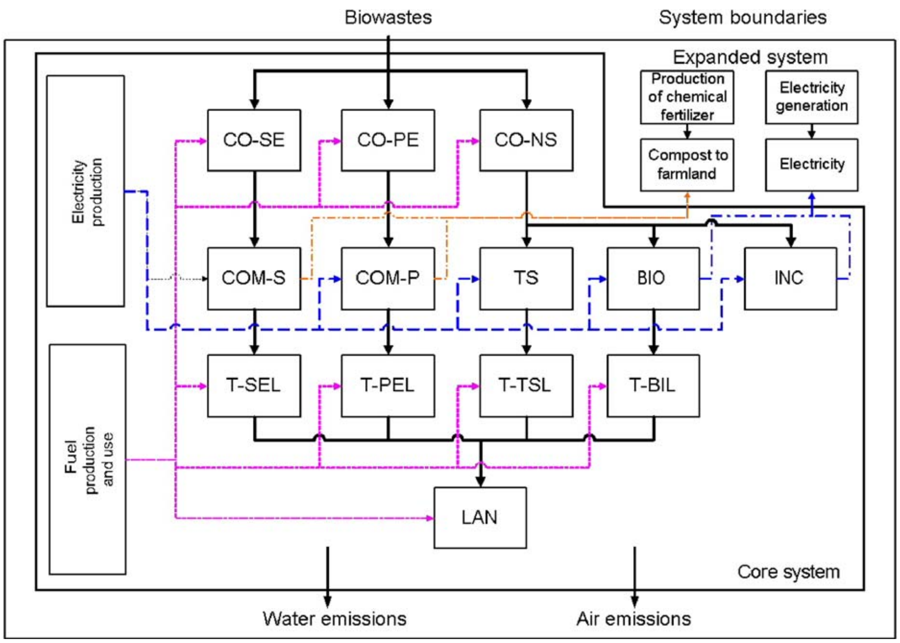

Fig. 1. Processes included in the actual system.

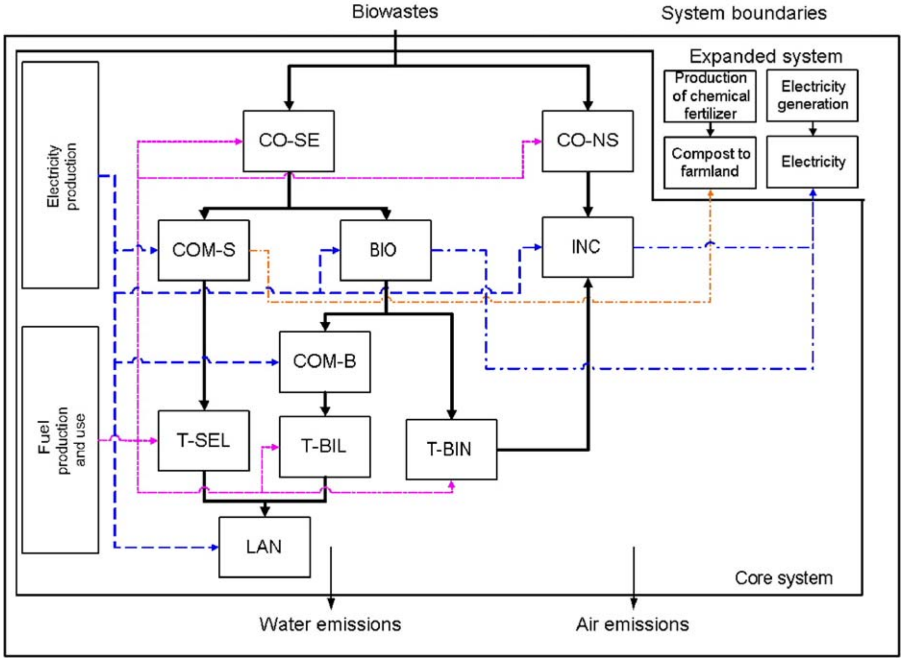

Fig. 2. Processes included in the future system.

2.2.2. *Compost manufacture*

Thirty kilowatt hour of electrical power supply are needed per ton of biowaste incoming in the process (McDougall et al., 2001). The generation of leachates is not considered in COM-S and COM-P because they are re-circulated, making up a closed circuit as established by Álvarez et al. (2000). COM-B does consider the treatment of leachates.

2.2.3. *Biogasification*

Fifty kilowatt hour of electrical power per ton of biowaste coming into the digester were considered (McDougall et al., 2001) and a proportion of 90% of water and 10% of solids is used during digestion (AMR, 1997). The electrical power produced in the actual system is 49 kWh/t (AMR, 2003) and 150 kWh/t are considered for the future (McDougall et al., 2001). In the actual system the refuse of BIO is transported to landfill (T-BIL), in the future that remaining of BIO (22% according to McDougall et al., 2001) comes into the process of manufacturing of compost (COM-B). The surface used for this process is 3 ha actually and 15 ha in the future.

2.2.4. *Incineration*

According to McDougall et al. (2001), the inputs for INC are 80 L water/t of waste and 70 kWh electrical power/ton of waste. The outputs are 520 kWh electrical power/t of waste incinerated and 250 kg slag/t. For the two systems analyzed, the surface used is 6 ha. The slag is assumed to be used for the construction of roadways therefore they are not included within the analysis.

2.2.5. Transfer station

The requirements of electricity are 0.5 kWh/t for compacting (estimations based in data by Pakawaste Co., 2003) and a surface of 2 ha.

2.2.6. Transport to finalist treatments

Include TSL, T-SEL, T-PEL, T-BIN and T-BIL. The first is carried out in trucks with a capacity of 25 t that have a consumption of 0.5 L diesel/km and cover around 10 km/travel. The latter four transports take place in trucks with 7.23 t of load capacity, with consumption of 0.25 L diesel/km. It is estimated that T-PEL covers a travel of 50 km/route; T-BIN of 40 km/route; T-SEL of 44 km/route in the actual system and 60 km/route in the future system. Finally, T-BIL covers 46 km/route in the actual system and 60 km/route in the future system.

2.2.7. Sanitary landfill

Actually, the biowaste coming from the transfer station, the refuse from BIO and the refuse from COM are placed in the traditional sanitary landfill (LAN). The atmospheric emissions and the production of leachates resulting from that disposal are considered to last for 30 years (McDougall et al., 2001).

0.45 t clay/t of waste are used as covering material of the landfill (Doménech and Rieradevall, 2000), but remaining of the compost manufacturing displaces a part of the clay. The generation of biogas is 250 N m^3/t of waste, of which the 40% is collected to produce 1.5 kWh/N m^3 (McDougall et al., 2001). One hundred and fifty liters of leachates are produced per ton of waste (McDougall et al., 2001), of which 70% is collected for its treatment (Doménech and Rieradevall, 2000). 1.3 L diesel/t of waste disposed is needed for the compact machinery. In the actual system the estimated surface is 25 ha. (Doménech and Rieradevall, 2000).

For the future system it is considered a rectangular baling-wrapping technology for the sanitary landfill, which requires 8.8 kWh/bale compacted and generates 9 L of compacting liquid per ton of waste (Baldasano et al., 2003). A surface of 5 ha for the disposal of refuse generated in the future system is estimated.

2.3. Life cycle inventory

The inventory of atmospheric emissions and water loads by the use and production of electrical power and fuels were calculated following BUWAL 250 (1998). The compounds emitted to the atmosphere by the production of chemical fertilizers were entered as emissions saved due to the replacement of chemical fertilizers by compost, according to McDougall et al. (2001). The atmospheric emissions, water loads and waste generated by power plants when generating electricity were also taken into account as environmental loads saved when electrical power was produced within the processes. The emission factors for power generation were suggested by BUWAL 250 (1998), according to the profile for Catalonia in the year 2000: coal 2%, oil 4.6%, natural gas 18.9%, hydroelectrical power 12.2% and nuclear 62.3% (based on Generalitat de Cataluña (2002)). The emissions by compost production were adopted from Flotats (2002) and the emissions from biogasification were set by McDougall et al. (2001). The emissions by incineration were estimated according to the emission factors for fermentable material of the Research Triangle Institute (RTI, 1997), which take into account the efficiency of pollutants removal during the process. In the scenario of sanitary landfill for the year 2002, the emissions are produced by the anaerobic decomposition of the fermentable material (McDougall et al., 2001) and are taken into the inventory reported by Waste Management International (WMI, 1994).

2.4. Life cycle impact assessment

The atmospheric emissions and water loads estimated through LCA for each process of the two systems analyzed were entered in the software Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI) developed by the US EPA (Bare et al., 2003), to obtain the life cycle assessment impact (LCAI). That consists in giving a value of the potential impact within the categories considered. In this case, the categories are: depletion of the ozone layer (kg CFC-11), global climate change (kg CO_2), acidification (moles of H^+ equivalent), eutrophication (kg N), photochemical smog (g NO_x equivalent), ecotoxicity (kg of 2,4-dichlorophenoxyacetic acid), human health under the criterion of air pollutants (total disability-adjusted life years, DALYs), human health under the criterion of cancer (kg C_6H_6 equivalent), human health under the criterion of no-cancer (kg C_7H_7 equivalent), diminution of fossil fuels (MJ), land use (threatened and endangered species) and water use (m^3).

3. Results

Figs. 3 and 4 show the potential impacts for each of the management systems analyzed and the net contributions of each process on each of the impact categories.

Fig. 3a presents the acidification potential. For the actual system, the process with the most important contribution to acidification is CO-NS followed by CO-SE. For the future system, the results revert; CO-SE takes the first place and CO-NS is the second process. In both cases the main contributor to this impact is the nitrogen dioxide generated by the trucks that collect the biowaste. In the future system the acid contributions of COM-S are incremented, since the scenario considers a rise in the compost manufacturing with biowaste from the selective collection. BIO has negative contribution in the future system because it would generate electrical power; therefore, it saves emissions that would be generated when producing electricity under the profile of Catalonia.

The graphic of ecotoxicity (Fig. 3b) indicates a decrease of the potential impact for the future system. In the actual system the INC process dominates, because of the emissions of heavy metals in the incineration of biowaste. LAN also contributes with dioxin emissions that biowaste placed in the landfills during year 2002 will emit along 30 years. LAN does not contribute to ecotoxicity in the future system, since the waste arriving at landfills will be placed under the baling-wrapping technology, which does not generate ecotoxic emissions.

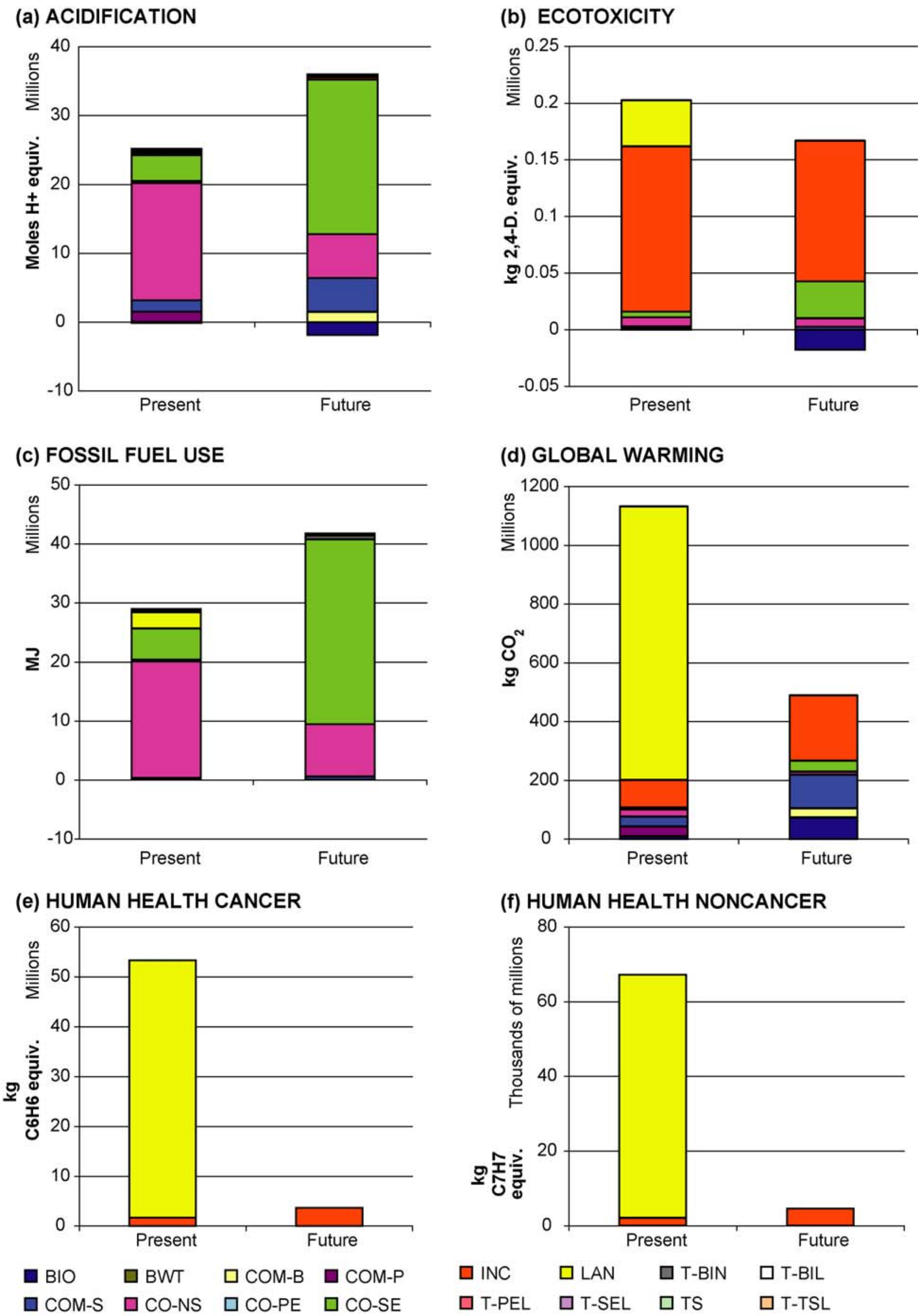

Fig. 3. Potential impacts for the two biowaste management systems analyzed: (a) acidification, (b) ecotoxicity, (c) fossil fuel use, (d) global warming, (e) human health cancer and (f) human health non-cancer.

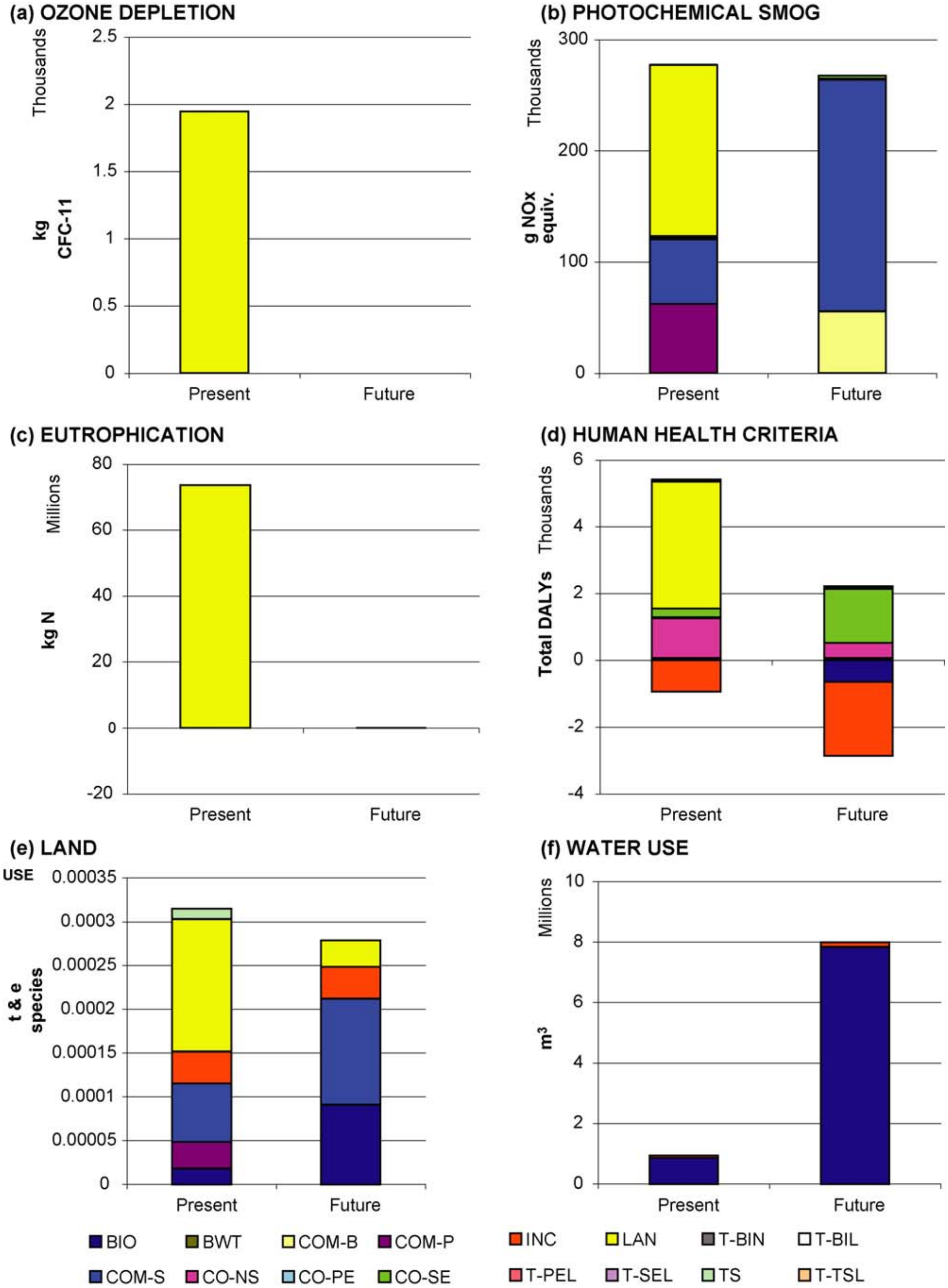

Fig. 4. Potential impacts for the two biowaste management systems analyzed: (a) ozone depletion, (b) photochemical smog, (c) eutrophication, (d) human health criteria, (e) land use and (f) water use.

CO-SE increases its contributions to this impact category. BIO presents negative values because this system saves emissions that will be generated under the energetic profile of Catalonia.

Fig. 3c indicates an increase in the fossil fuel use for the future which is caused by the planned increase in the selective collection. For the actual system CO-NS is the process with the highest contribution. In both cases the most used fuel is diesel.

The potential impact on climate change will be diminished with the future biowaste management system, as shown in Fig. 3d. In the actual system the dominant process is LAN, mainly because of the methane emissions that the biowaste will generate along 30 years. The second place is for INC due to the carbon dioxide emissions. For the future system, the biowaste placed in the landfill (LAN) with the technology of baling-wrapping will not generate emissions that will contribute to the global warming, but some contributors will be INC, COM-S and BIO because of CO_2 emissions.

In the case of human health under the criterion of cancer, Fig. 3e shows an important decrease in the potential effect for the future because LAN will not emit C_6H_6 equivalent. The emissions for this system are only caused by dioxins emitted by INC.

The potential impact on human health under the criterion of no-cancer notoriously decreases (Fig. 3f) due to the removal of LAN emissions in the future system, when only INC contributes. Both LAN and INC contribute mainly because of their emissions of dioxins.

Fig. 4a depicts that the potential impact on the ozone layer will be removed with the management system proposed for the future system.

Fig. 4b shows that the NO_x equivalent has similar amounts for both systems analyzed. In actual system the emissions are generated by LAN, COM-S and COM-P. In future system LAN stops contributing to this effect, but both COM-S and COM-B generate a higher impact.

The potential impact on eutrophication is only present in the actual system (Fig. 4c). Here LAN is the process responsible for this impact due to the leachates that are produced in the traditional landfill. With the new disposal technology proposed for the future system the non-controlled emissions of ammonia and chemical oxygen demand are saved.

Fig. 4d shows an important reduction of the potential impact on human health under the criterion of pollutants for the future system. This is because LAN process in the future scenario does not emit PM_{10}. Besides INC and BIO increase the electrical power generation, therefore enlarges the savings of PM_{10} and SO_2, which would be generated when producing this power with the energetic profile of Catalonia.

The potential impact on the land use is determined as a function of the number of threatened or endangered species that are displaced because of the land use. In this sense, Fig. 4e shows that for the future systems, LAN decreases the impact, INC remains constant and TS and COM-P stop affecting. However the impact does not notoriously decreases, because BIO and COM-S are processes that increase the land use.

Fig. 4f depicts the impact on the water use, which increases for the year 2006. This impact is clearly defined by BIO and INC.

4. Discussion

4.1. Systems analyzed

Seven out of 12 potential impacts analyzed are decreased with the future biowaste management system: ecotoxicity, global warming, human health under the criteria of cancer, non-cancer and pollutants; formation of photochemical smog and land use. Two of them are removed: depletion of the ozone layer and eutrophication. Three of them are increased: acidification, fossil fuel use and water use.

4.2. The waste collection

The potential impacts of acidification and the fossil fuel use are higher for the future system due to the increase of the selective collection. According to Baldasano et al. (2002), this is a process where the yields decrease since there is a lower compacting of the fermentable fraction in the collecting trucks in order to avoid the production of leachates and the later processes of biologic fermentation. This involves more routes and a higher formation of nitrogen dioxide that contributes to the acidification. Additionally, the selective collection and the non-selective collection are processes presenting PM_{10} emissions, impacting significantly in the category of human health criteria by mercury, which is the main contributor to ecotoxicity in these processes.

In order to optimize the collection system, focusing in reducing the emissions of greenhouse gasses and saving energy, Weber et al. (2002) recommend to minimize the frequency of collection, which is not possible in the case of biowaste during summer, because temperatures of 35 °C are reached in the BMA, and that would generate the decomposition of materials.

4.3. Compost manufacturing

The compost manufacturing with biowaste coming from the selective collection contributes (although not significantly) to the potential impact of acidification by the ammonia emissions, which become higher when increasing the amount of biowaste treated in the future system. Mendes et al. (2003) state that the treatment of gases emitted by compost manufacturing may reduce part of the potential impact in this category, but this process was not considered within this study due to the technological differences in the treatment of the emissions identified in the composting plants.

In addition, the compost manufacturing as a whole promotes the potential global warming, mainly because of the carbon dioxide emissions which, according to Edelmann et al. (2000), cannot be prevented in the case of the degradation of fermentable matter. The emissions of carbon dioxide become determined by the degradation of the fermentable material and by the use of electricity in the process, as stated by Kübler and Rumphorst (1999). In this work we considered a saving of emissions by the substitution of chemical fertilizers by compost. According to McDougall et al. (2001) and AMR (1997), the compost generated can be considered as a low-graduation fertilizer.

The formation of photochemical smog is an impact category in which the processes of compost manufacturing are determinant. This is caused mainly by the VOCs emissions, which are notoriously increased in future system because of the rise of the compost manufacturing from selective collection; and also because of the compost manufacturing after biogasification.

The land use is another category in which the processes of compost manufacturing contribute due to the surface needed. In the actual system, four out of the five installations that are located in the BMA use the open system that requires a wider area than the decomposition tunnels. For the future system, it is programmed to open two more plants that will work with decomposition tunnels (AMR, 1997), which occupy a smaller area per treated ton of waste. Therefore, we notice that despite the compost manufacturing increases the land use for the future system, this could be even higher if open systems are implemented in the plant programmed.

As shown in Section 3, the compost manufacturing contributes to the generation of more potential impacts than biogasification. Bjorklund et al. (1999) and Edelmann et al. (2000) state that the compost manufacturing on a wide scale increases the environmental impacts comparing with anaerobic digestion. However, this process presents lower potential impacts than the incineration and sanitary landfill. Furthermore, it saves the emission of greenhouse gases since it deviates biowaste from the sanitary landfill, where methane and other greenhouse gases are produced (Weitz et al., 2002).

On the other hand, Favoino and Hogg (2002) report other benefits of composting that have not been evaluated in this study: (1) it allows the capture of nutrients since it reduces the mineral lixiviation when increasing the content of organic matter in the soils; (2) it reduces the production of nitrous oxide since it liberates the N consistently with the uptake of N by the root of the plant, unlike chemical fertilizers which generate N_2O due to incomplete processes of nitrification and de-nitrification; (3) it promotes the fertility of the soil; (4) it reduces the erosion; (5) it reduces the irrigation requirements. If these additional advantages were taken into account, the compost manufacturing would be even more environmentally favorable. However, we should bear in mind that all the aforementioned advantages are linked to the quality of the compost.

4.4. Transfer station

The transfer station is a process that is only presented in the actual system. This has only an evident contribution, although not significant, in the category of land use. In spite of using electrical power as inflow it does not impact any other category.

4.5. Biogasification

The increase of biogasification for the future system will to raise the water use, because the technology Linde KCA Humid is used. It presents a water consumption of 7.6 m^3/t of biowaste treated (AMR, 1997). However acidification, ecotoxicity and human health criteria going to be mitigated due to the generation of electrical power such as Finnveden (1999) reports.

Edelmann et al. (2000) and Mata-Álvarez (2001) agree that the plants of anaerobic digestion are better from an ecological point of view than other treatments of fermentable waste, because they do not require external electrical power coming in a great part from fossil fuels. They generate electrical power, and that represents positive effects in nearly all the impact categories because of the saving or compensation of non-renewable energy.

4.6. Wastewater treatment post-biogasification

This process does not present significant potential impacts because it benefits from the electrical power generated through biogasification. Thus, just the direct emissions from the biologic treatment process were added, which are negligible compared to the rest of processes.

4.7. Incineration

For the actual system the incineration highly contributes to the potential impact of ecotoxicity (72% of the contributions) because of the emissions of heavy metals and dioxins. It also contributes (less significantly) to the global warming with carbon dioxide; to the human health under the criteria of cancer and non-cancer with dioxins; to the land use and to the water use. On the other hand, it quenched the potential impact on human health under the criteria of pollutants because of the saving of PM_{10} and SO_2 emissions since it generates electrical power.

For the future system, the contributions of the incineration to the ecotoxicity decrease and there is a higher mitigation on human health under the criteria of pollutants due to the increase of electrical power generated. On the contrary, there is a higher impact on global warming, on human health under the criteria of cancer and non-cancer.

The incineration of fermentable waste generates emissions of dioxins, furans and heavy metals, which are present in the biowaste because of their deposition through the rain and the air in the biomass (Edelmann et al., 2000; RTI, 1997). In the analysis performed, the incineration is the process that presents a higher potential impact on toxicity for ecosystems without reaching preoccupant levels. Schuhmacher (2001) performed a study for the incinerator located in Montcada i Reixac (in the BMA), and reports that due to the decrease of the emissions of dioxins and furans of the incinerator; the surrounding grass also shows a decrease in the concentration of these composites.

The potential impact on global warming for the future system presents an increase with respect to the actual system, but this is not proportional to the increase of incinerated biowaste due to the saving of GHG emissions that are added by electrical power generation. However, this study does not consider the saving of GHG that may be produced if incinerated waste would be treated in landfill, as suggested by Weitz et al. (2002). On the other hand, Smith and Brown (2002) report that the incineration of fermentable biowaste generated net benefits with respect to the GHG emissions, especially if incineration includes electrical power and heat generation. It does not agree with the results of this study, probably because the exploitation of heat power is not included within the process. It is also important to highlight than in this case an unreal situation was evaluated. As stated by Smith and Brown

(2002) this fraction cannot be incinerated independently from the rest of fractions because the calorific power would be under the levels for which incinerators are designed.

As commented before, the future system depicts a slight increment in the potential impact on human health under the criteria of cancer and non-cancer. In both cases, the incineration is the only process responsible for these impacts. The main contributor to these categories is the emission of dioxins, which have traditionally being a cause of worry because of their carcinogenic potential. Domingo (2000) indicates that despite the incineration of waste has been considered as an important source of dioxins, the inventories made in the last years have shown that this process (after the recent adaptations to UE's legislation) presents a much lower impact.

Although it is nearly impossible to verify straightforward whether a modern incinerator involves or not a direct impact on health, nowadays estimations carried out through diverse risk evaluations allow concluding that these installations do not involve an additional risk for the residents in their proximities on the actual circumstances.

4.8. Transport to finalist treatments

Several process are included here: transport of compost refuse to landfill (T-SEL, T-PEL), transport of biogasification refuse to landfill (T-BIL), transport of biogasification refuse to incineration (T-BIN) and transport from transfer station to landfill (T-TSL).

None of the transports to finalist treatments gets to be significant on the generation of the potential impacts analyzed. However it should be highlighted that the location of the landfill planned for the future system is not defined and an arbitrary average distance of 60 km per route was considered for the analysis.

4.9. Landfill

For the actual system, the landfill is the most important contributor in the following impact categories: global warming, human health under the criteria of cancer, non-cancer and pollutants; depletion of the ozone layer, formation of photochemical smog, eutrophication and land use. Additionally, it presents contributions that are not determinant in ecotoxicity and fossil fuel use. Furthermore, this process involves the highest potential impacts, which agrees with the reports of Mendes et al. (2003) for the city of Sao Paulo (Brazil). On the contrary, the landfill planned in the future system with the baling-wrapping technology contributes only to the land use and not significantly.

With respect to the potential impact on global warming, Smith and Brown (2002) report that the sanitary landfill is clearly the worst option for the management of biowaste due to the important GHG emissions generated. Weitz et al. (2002) indicate that diversifying the destiny of the waste, the efficiency in the collection of biogas, the degree of energy recovery and the amount of handled materials are the key to reduce the emissions of GHGs. However, the waste disposal under the baling-wrapping management system offers other advantages as the removal of methane emissions (Gassó and Baldasano, 2000).

The potential impact on eutrophication in fact is not presented, since the landfill is located in a calcareous massif where the carbonated rocks undergo a continuous dissolution which facilitates the water filtering and the accumulation of ground water. Since the landfill is placed on this ground so permeable and porous, the leachates go through the soil (30%, according to Doménech and Rieradevall (2000)), get to the aquifers and pollute water.

Another potential impact of the landfill in the actual system is the land use. According to the results provided by TRACI (Bare et al., 2003), the surface covered by the biowaste generated in the actual system could be pushing out 0.003 threatened or endangered species. However, the TRACI model is settled on databases specific for the United States that do not necessarily agree with the environmental characteristics of the area of Garraf (place where the landfill is located), which is a location with a high diversity, characteristic of the southern Mediterranean and declared Natural Park on 1986. Despite the landfill existed in that year, nowadays it has exceeded the limits of the protected area. Furthermore, we should bear in mind that this study only considers the fermentable fraction of the waste and a total study of the waste would indicate an increase in the land use. Thus, the number of threatened or endangered species would increase with the possibility of being pushed out.

On the other hand, we have the baling-wrapping landfill for the future system. In spite of the environmental advantages that it provides in this study, it should be considered as a new technology, whose experiences are limited on time and that requires of monitoring that allows evaluating the impacts on a long term. Baling-wrapping landfill is a potentially less problematic process than traditional controlled landfill (Baldasano et al., 2003).

4.10. Ranking of technologies

If we analyze the results from the point of view of the biowaste treatment technologies (nor transport neither collection), a ranking could be obtained. In this section, the main potential impacts reported for biowaste management are analyzed.

For global warming the results demonstrate that traditional controlled landfill is the main contributor of GHG, followed by incineration, composting and biogasification. This ranking agrees with Eriksson (2000) where incineration, composting and biogasification are compared and the incineration is identified as the principal contributor of GHG, followed by composting and biogasification. Besides, Mendes et al. (2003) compare the traditional controlled landfill, composting and biogasification and identify the controlled landfill as the most important generator of GHG, followed by composting and biogasification.

The results indicate that the traditional landfill is the only technology that produces potential impacts in eutrophication. This result is consistent with Aye and Widjaya (in press) and Mendes et al. (2003) where the traditional landfill is the principal origin of eutrophication, followed by compost and biogasification. In this study compost and biogasification do not generate eutrophication because it is considered that the leachates are re-circulated in the case of composting, and treated in a wastewater treatment plant in biogasification process.

If the collection processes are eliminated from this analysis, the composting is the most important cause of acidification, which agrees with Eriksson (2000) and Mendes et al. (2003).

4.11. The model

TRACI is a model developed by the US EPA that represents the potential impact categories for the United States (Bare et al., 2003). Thus, some results may not reflect accurately the reality of the BMA.

5. Conclusions

Seven out of 12 potential impacts analyzed decrease with the future biowaste management system: ecotoxicity, global warming, human health under the criteria of cancer, non-cancer and pollutants; formation of photochemical smog and land use. Two of them are removed: depletion of the ozone layer and eutrophication. Three of them increase: acidification, fossil fuel use and water use.

The important decrease of the potential impacts on ecotoxicity, global warming, human health under the criteria of cancer, non-cancer and pollutants, as well as the removal of the potential impact on the depletion of the ozone layer and eutrophication are determined because of the change of disposal technology.

The process that generates a higher potential impact is the traditional sanitary landfill in the actual system.

The processes that increase their impact for the future system are the selective collection and the compost manufacturing; this is caused by the increase in the amount of biowaste in these treatments.

The processes that increase their benefits for the future system are incineration and biogasification, since it generates electrical power, which saves emissions that contribute to the acidification, ecotoxicity and human health by pollutants.

The overall of the transports to finalist treatments do not generate any significant potential impact, because their emissions and/or loads to the water are not important when compared to the flows for the rest of processes.

The model used (TRACI) is based on methodologies that allow representing the potential effects for the United States (except in the cases of global warming, depletion of the ozone layers and fossil fuel use). In the case of the land use, results may not accurately represent the reality of the BMA.

The results of this work allow supposing that the future biowaste management system is environmentally better than the 2002 system. However, for a conclusive a statement, it is required:

(a) To perform a life cycle analysis of the two integral waste management systems, where all the waste fractions are involved.
(b) To develop the valuation step of LCA in order to get an index that facilitates the making decision process.

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