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Full Length Research Paper

Life cycle assessment of biological-mechanical treatment in solid waste management

Heydar Rezaeyeh Esmaeil[1,2]*, Sumiani Yusoff[2], Jafar Nouri[1] and Jahangir Asadi[3,4]

[1]Department of Environmental Management, Science and Research Branch, Islamic Azad University, Tehran, Iran.
[2]Faculty of Engineering, University of Malaya, Kuala Lumpur, Malaysia.
[3]National committee for EMS Standardization, Iran.
[4]ISO/TC 207, Iran.

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Mechanical-biological waste treatment process commonly produce an organic rich fraction containing nutrients and organic matter which have the potential to improve physical, chemical and biological health of soil. Based on recommended BMT-based integrated MSW management system, life cycle assessment is employed to compare the environmental impact potential (EIP) of two BMT-based waste treatment strategies (BMT-incineration and BMT-landfill) with traditional landfill and incineration in Kahrizak, Iran. The results show that the landfill has higher impact on climate change and acidification while using BMT in landfill has decreased the effect on the climate change and also 'incineration scenario' has highest impact on fossil fuel, climate change and respiratory inorganic. While using BMT –incineration has decreased the effects on climate change and fossil fuels. The results verify that BMT based on MSW management would be environmentally reasonable and helpful to develop integrated MSW management system in Kahrizak, Iran.

Key words: Life cycle assessment, based waste treatment strategies, waste.

INTRODUCTION

Iran is a vast country with total land area of 1,648,195 km^2 divided into 26 provinces. Growth of environmental awareness in Iran has increased the attention that has been paid to solid waste management (SWM) and urban problems in recent years. Solid waste takes a variety of forms and comes from a wide range of sources. It consists of all kinds of wastes arising from social, economic and industrial activities. During the past 30 years, the quantity and composition of solid waste generated in northern Iran have been changed, but the methods of collection, transport and disposal have still remained the same. As a result, some provinces are facing serious environmental problems. Most of the rivers for instance are polluted and have been converted to dumping sites for all types of wastes arising from industrial, agricultural and municipal activities. Within the last few years, environmental issues are increasingly becoming more important in Iran and the world over like lack of environmental monitoring systems and necessary equipment's in many industrial estates of Iran. Self regulated environmental management tools like the ISO 14000, EMAS and 'life cycle' assessment could be adopted by the industries to structure, their environmental efforts to the benefits of themselves and the environment (Sumiani, 2005). In order to evaluate the environmental effects of a waste management (WM) system, it is necessary to consider all of the processes involved. A successful integrated solid waste management system, according to US EPA (1995) includes three parts: source reduction, which is the most preferred method followed by recycling and composting, and, lastly, disposal in combustion facilities and landfills.

Biological and mechanical treatment (BMT) process, as a pre-treatment method for MSW which always followed by compost, incineration and landfill, dates back to 1970s in Europe has been widely spread in Germany and Austria

*Corresponding author. E-mail: hrezaeyeh@siswa.um.edu.my.

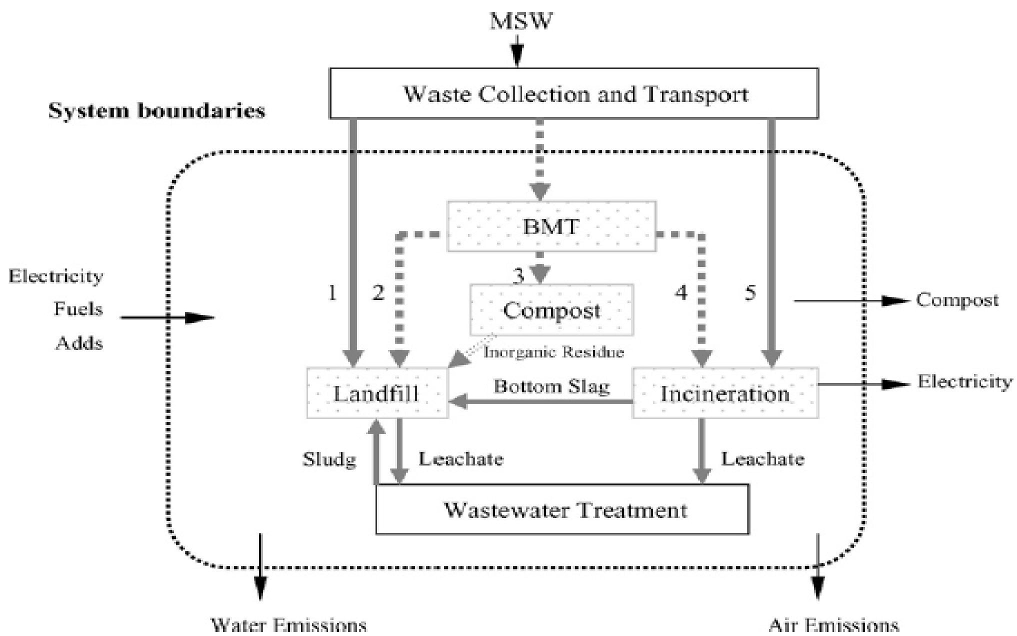

Figure 1. The system boundaries of the four different solid waste treatment methods.

are developing quickly in Italy, UK nowadays (Adani et al., 2004; Slater and Frederickson, 2001). BMT can decrease the amount and volume of MSW, stabilize the organic materials and recover the recyclables (Archer et al., 2005; FoE, 2004; SITA, 2004). Currently, the amount of municipal solid waste (MSW) generated in Kahrizak is about 1200 t/day. The great mass of MSW is directly treated by incineration and landfill without any pretreatment except for compost. Meanwhile, only 5% of MSW generated from Kahrizak are recycled by separation. Life cycle assessment (LCA) is a system analysis tool that has been recently applied to MSW management (Barton et al., 1996; Weitz et al., 1999; White et al., 1999) was chosen for evaluation to ascertain if environmental benefits could be obtained through a change in the MSW treatment system. In this paper, LCA is used for comparing environmental impact potential (EIP) of four different alternative waste treatment strategies, these are landfill, incineration, BMT-landfill and BMT incineration. This study has been performed in kahrizak during 2009 to 2010 in Iran.

METHODOLOGY

Life cycle assessment (LCA) is a tool which has a global vision of the production system in all processes and the operations interact from the extraction of raw materials to the end of life are analyzed in terms of input and output, and also encompasses the burdens associated with resource depletion (ISO, 1997). The life cycle assessment was performed for four scenarios of waste management: land filling, incineration, BMT land fill and BMT incineration. The data for the assessment was collected from three different sources:

1) Sampling at solid waste disposal sites (SWDS).
2) Calculating data (DOE, 200).
3) Environmental pollution control system facilities.

Goal and scope definition

The goal of this study is to get the difference of environmental impact between four waste treatment strategies which are: Landfill, incineration, BMT-landfill and BMT incineration. The scope of this study evolves the environmental consequences of solid waste disposal. This assessment uses the LCA software SimaPro 7.1 and the LCA method Eco-Indicator 99 (H). In this study one tone of MSW is chosen as the functional unit for each treatment method during the life cycle assessment.

System boundaries

In an LCA, the choice of system boundaries is crucial for the results and their interpretation. Transportation was assumed to be identical in all scenarios, therefore these transportation stage before the waste treatment were omitted (Figure 1).

RESULTS

Life cycle inventory

Tables 1 and 2 shows the 'life cycle inventory' of landfill and incineration. Energy consumption, resources input and recovery (electricity, compost) and pollutant emissions to the atmosphere (CO_2, CH_4, SO_2, NO_2, N_2O, H_2S, HCl, NH_3) and water (N, P) were estimated for all scenarios. The primary data come from the incineration

Table 1. Physical composition (as wt. %) of MSW (DOE of Iran 200).

Component	Content (%)
Organic garbage	55.58
Paper	5.68
Plastic	22.43
Wood	2.8
Textile	3.3
Metal	2.58
Glass	4.22
Ash	2.59

Table 2. Life cycle inventory of MSW Iran (DOE of Iran 2007).×

Variables	Landfill	BMT-IAN	Incineration	BMT- INC
Energy (MJ/tMSW)	6.07×10	5.51×10	2.1×10^{2}	1.1×10^{2}
CO2 (kg/tMSW)	8.94×10	6.35×10	6.1×10^{2}	7.8×10
CH4 (kg/tMSW)	2.23×10	1.1×10	3.8×10	1.5×10
CO (kg/tMSW)	2.13×10^{-3}	3.34×10^{-4}	6.8×10^{-1}	7.3×10^{-3}
NOx (kg/tMSW)	0.07×10^{-1}	0.02×10^{-2}	3.5×10^{-1}	4.5×10^{-3}
SO2 (kg/tMSW)	2×10^{-3}	1.2×10^{-4}	6.3×10^{-1}	7.8×10^{-3}
HCL (kg/tMSW)	5.4×10^{-4}	3.2×10^{-5}	8×10^{-2}	6×10^{-4}
HF (kg/tMSW)	2.4×10^{-2}	1.2×10^{-1}	2×10^{-2}	3×10^{-3}
H2S (kg/tMSW)	4.8×10^{-1}	5.6×10^{-2}	0.01×10	0.02×10^{-1}
NH3 (kg/tMSW)	4.5×10^{-1}	3.3×10^{-2}	0.07×10^{-2}	0.85×10^{-4}
N (kg/tMSW)	4.8×10^{-3}	2.3×10^{-4}	4.1×10^{-3}	5.3×10^{-5}
P (kg/tMSW)	3.1×10^{-2}	3.64×10^{-4}	3.1×10^{-4}	4.7×10^{-3}

plant and landfill yard and Department of Environment in Iran. In this paper, CO_2 emissions from biogenic sources are not counted. According to US EPA (2002), CO_2 emissions from human activity do not enter the natural carbon cycle. Consequently, CO_2 emissions from burning fossil fuel are counted in this work. Likewise, CH_4 emissions from landfills are counted.

DISCUSSION

Life cycle impact analysis

The 'eco-indicator' 99 method was used as a LCIA for this study where it was listed 11 impacts classified into 3 damage assessment (Table 3):

Normalization

Normalization step is required in order to gain a better understanding of the relative size of an effect. The impacts of normalization were shown in Figure 2. Four major impacts had been highlighted. The landfill has the highest impact on the human health while BMT land fill has low effects on the human health.

Weighting

To facilitate decision making, the normalized impact indicators may be weighted to yield a single, all-embracing impact indicator through the use of a set of weighting factors. Figure 3 shows the weighting of four waste treatment scenarios. The highest effect is related to landfill, while BMT landfill has less effect on the climate change.

Characterization

The damage assessment of four waste treatment scenarios was shown in Figure 4. The landfill scenario (0.000446 DALY) and BMT- landfill (6.65E-05) have had the highest and lowest effect on human health respectively. Meanwhile the highest effect of ecosystem

Table 3. Damage assessment and impact according to eco-indicator 99.

Damage assessment	Unit	Impact
Human health	DALY	Carcinogen, radiation, respiratory organic and inorganic climate change and ozone layer.
Ecosystem	PDF*m2yr	Ecotoxicity, acidification, land use.
Resources	MJ surplus	Minerals, fossil fuels.

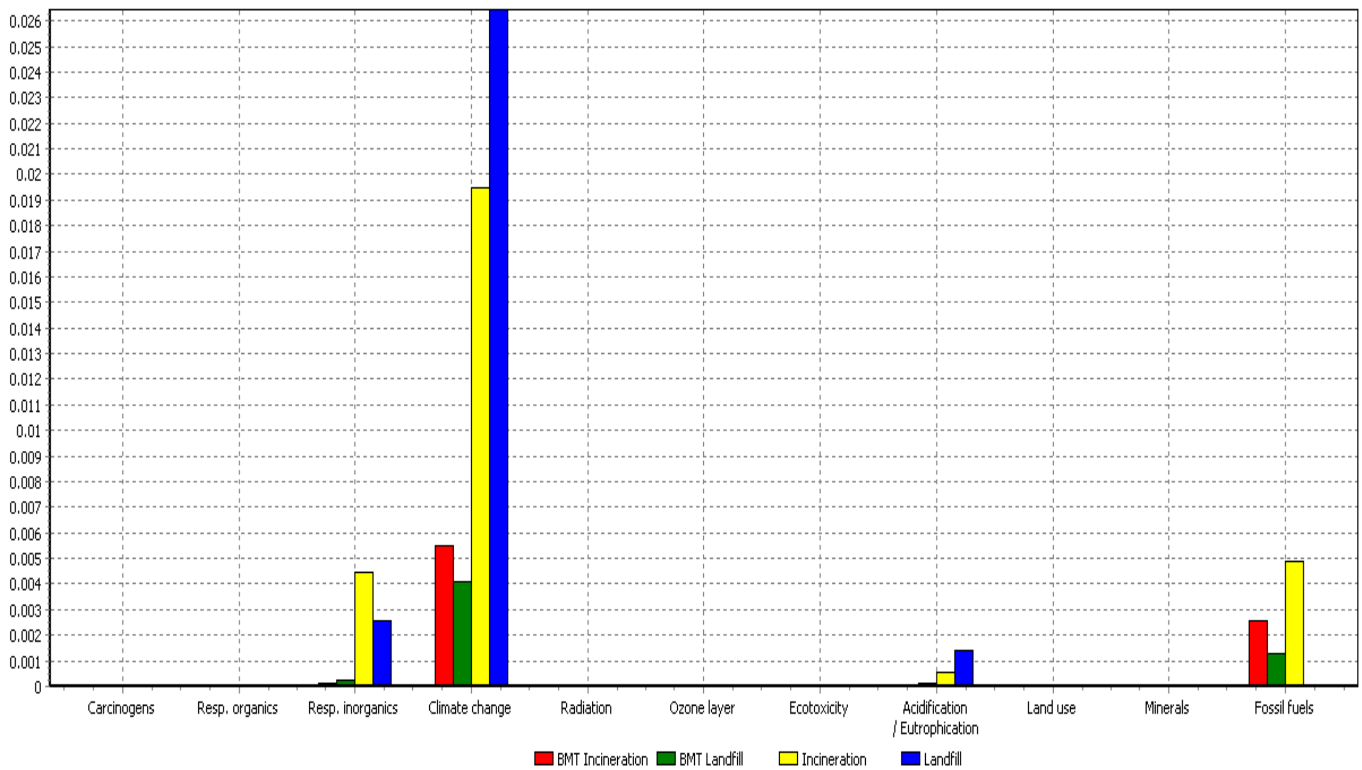

Figure 2. Normalization of four waste treatment strategies: Landfill, incineration BMT-landfill and BMT incineration.

quality is related to landfill scenario (7.048573 PDF* m2yr) however, BMT- incineration (0.586216 PDF* m2yr) had less effect on the ecosystem. Figure 4 also shows the incineration scenario has the highest effect on resource (40.95601 MJ surplus), while land fill has no effects. If the impact contributor is analyzed, the impact that contributed to the human health for landfill is from respiratory organics and climate change at the maximum value of 100% (1.14E-6 and 0.000406 DALY). High resource consumption for incineration scenario is generated from fossil fuels impact (40.9 MJ surplus).

Land fill scenario contributed 100% impact to respiratory organics (1.14E-6 DALY), climate change (0.000406 DALY) and acidification (7.05 PDF*m2yr) was shown in Figure 5. Incineration scenario contributed 100% impact carcinogenic (9.13E-8 DALY), respiratory inorganics (6.81E-5 DALY), radiation (2.74E-8 DALY), ozone layer (1.41E-8 DALY), ecotoxicity (0.0577 PDF*m2yr), land use (0.104 PDF*m2yr), minerals (0.0601 MJ surplus) and fossil fuels (40.9 MJ surplus). Table 4 shows the damage assessments from four waste treatment scenarios. And Table 5 shows the list of impact contributor from four waste scenarios

Conclusion

LCA was successfully conducted on the waste management in Iran. The presented case studies show how the environmental impact of new processes and technologies for the waste management requires the solution of methodological issues as the expansion of system boundaries and time boundaries. But the required effort is fully counterbalanced by the quantitative and

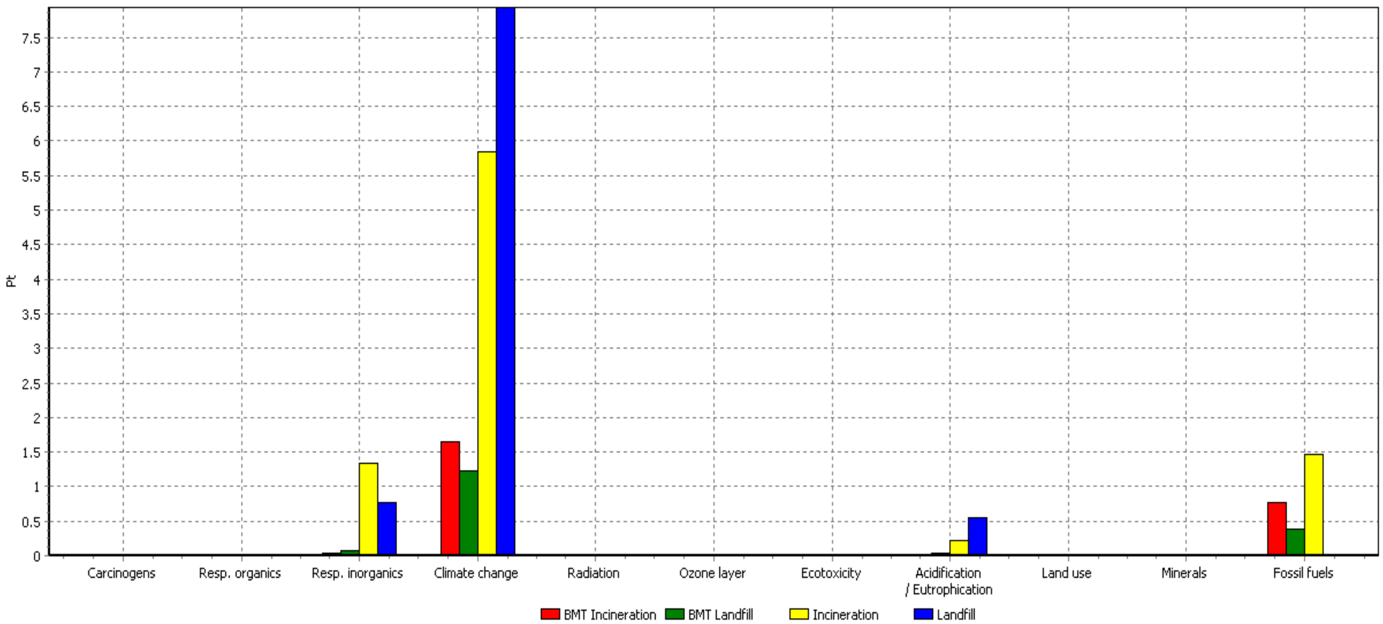

Figure 3. Weighting of four waste treatment strategies: Landfill, incineration BMT-landfill and BMT incineration.

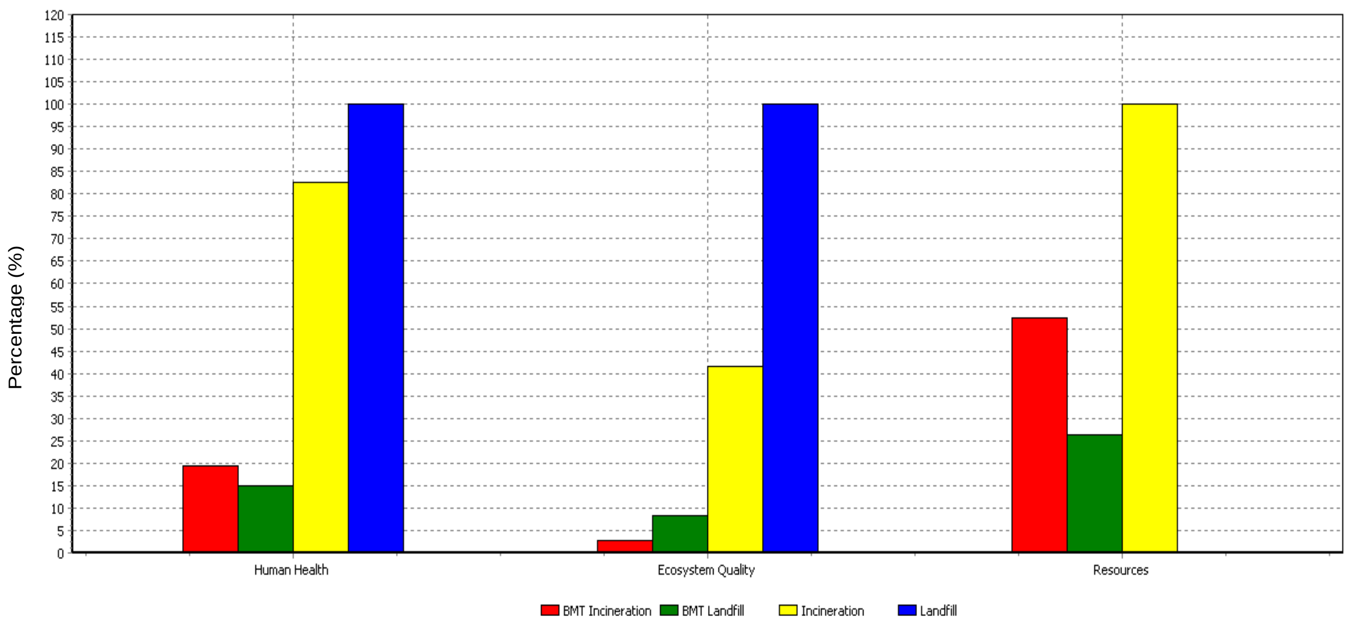

Figure 4. Damage assessment of four scenarios of waste treatment.

reliable information that an LCA can deliver. The results of life cycle assessment of the four different waste treatment strategies (landfill, incineration, BMT- landfill and BMT incineration) show the land fill has higher impact on climate change (7.93) and acidification (0.55) while using BMT in land fill has less effect on the climate change (1.23). Incineration scenario shows highest impact on fossil fuel (1.46), climate change (5.85) and respiratory inorganic (1.33) while using MBT -incineration decrease the effects on climate change (1.65) and fossil fuels (0.765). The results of this assessment can be useful for solid waste management in Iran. Then LCA methodology is also useful to identify different decision making process.

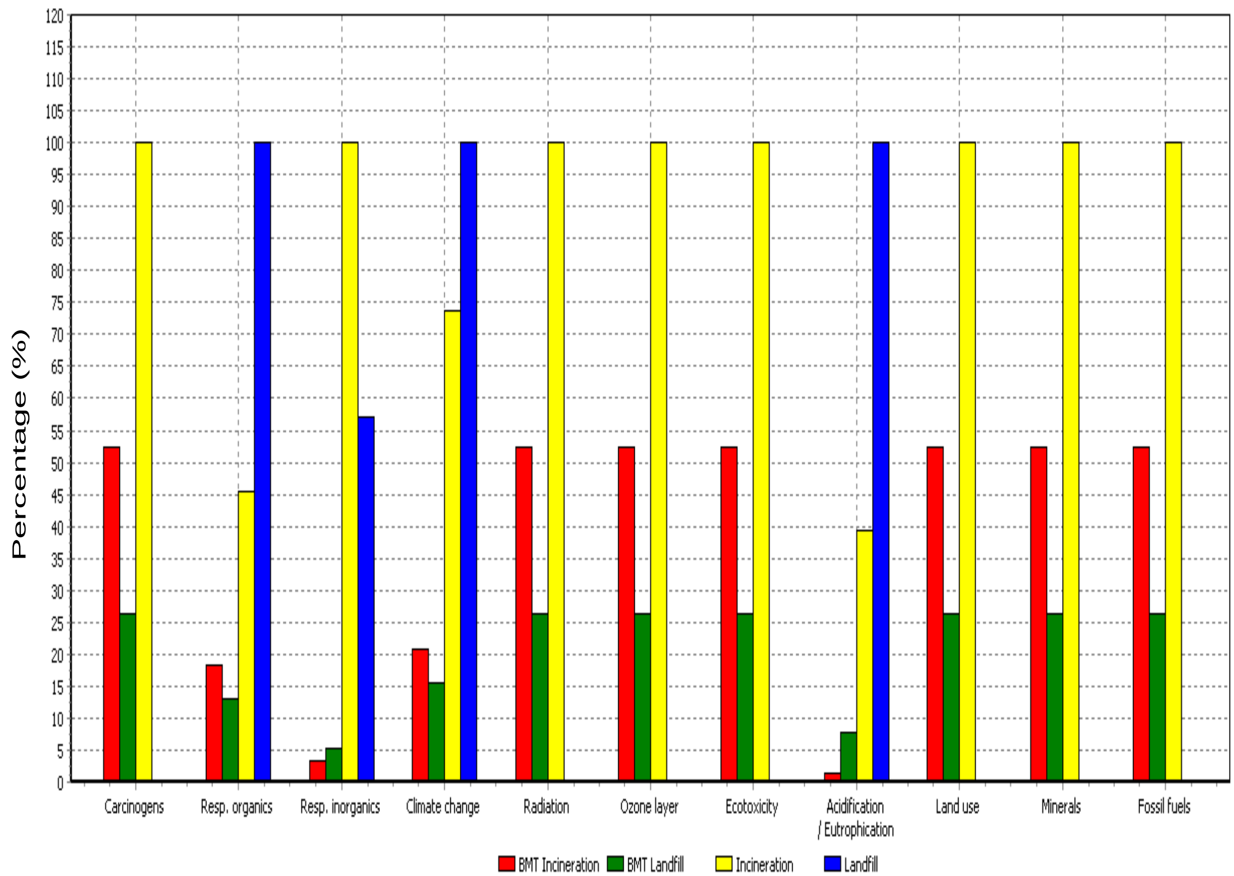

Figure 5. Damage assessment per impact categories.

Table 4. Damage assessments from four waste treatment scenarios.

Damage category	Unit	BMT Incineration	BMT Landfill	Incineration	Landfill
Human health	DALY	8.71E-05	6.65E-05	0.000368	0.000446
Ecosystem quality	PDF*m2yr	0.189081	0.586216	2.937404	7.048573
Resources	MJ surplus	21.45315	10.74608	40.95601	0

Table 5. List of impact contributor for four waste scenarios.

Impact category	Unit	BMT Incineration	BMT Landfill	Incineration	Landfill
Carcinogens	DALY	4.78E-08	2.39E-08	9.13E-08	0
Resp. organics	DALY	2.1E-07	1.5E-07	5.21E-07	1.14E-06
Resp. inorganics	DALY	2.27E-06	3.52E-06	6.81E-05	3.9E-05
Climate change	DALY	8.45E-05	6.28E-05	0.0003	0.000406
Radiation	DALY	1.44E-08	7.2E-09	2.74E-08	0
Ozone layer	DALY	7.41E-09	3.71E-09	1.41E-08	0
Ecotoxicity	PDF*m2yr	0.030233	0.015144	0.057717	0
Acidification/eutrophication	PDF*m2yr	0.104369	0.543783	2.775682	7.048573
Land use	PDF*m2yr	0.054478	0.027289	0.104004	0
Minerals	MJ surplus	0.031497	0.015777	0.060131	0
Fossil fuels	MJ surplus	21.42165	10.7303	40.89588	0

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