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Life Cycle Assessment of Municipal Solid Waste Management in Tehran

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Abstract

Due to increasing solid waste generation and their significant impacts on human health, environmental assessment of the management and disposal methods become more and more important. There are various disposal methods which are the combinations that originate from a wide range of solid waste management systems. In this study, municipal waste of Tehran (which totals to 7507.5 tons/day) is assessed according to five suggested scenarios. Life cycle assessment method was applied to compare the selected scenarios to select the most efficient solid waste management scenario in Tehran. Hence, the Eco-indicator 99 is utilized as the impact assessment method. The effects are evaluated in three categories including; effects on human health (organic substances, inorganic substances, climate change, ionizing radiation and ozone layer depletion), ecosystem quality (ecotoxic emissions, the combination of acidification & eutrophication and double coating) and resources (extraction of minerals and the fossil fuels). According to the results, scenario one leads to the most damage to the environment especially on the human health, whereas scenario four has the most positive impacts compared to the others. However, scenarios two and three are unsuitable due to their negative effects on human health. Although, scenario five shows positive results on the resources but again it has negative impacts on human health and ecosystem quality. Moreover, the most appropriate strategy in terms of land usage and energy consumption, again is scenario four (landfilling plus recycling and composting) is chosen as the most proper strategy.

Keywords: Life cycle assessment, Municipal waste, Landfilling, Composting, Recycling, Incineration

Introduction

In recent decades achieving goals such as public health and environmental quality have become of importance to societies and governments, which is directly linked with Solid Waste Management (SWM) systems. According to recent studies, there is a significant growth in the use of different waste disposal methods simultaneously for optimum results in waste management policies

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(Cherubini et al. 2009). Integrated Solid Waste Management (ISWM) has various definitions; the most common definition is, optimized waste management system with individual consideration of both environmental and economical aspects (Koroneos, and Nanaki 2012). One of the main methodologies able to reduce the environmental impacts by ISWM is the Life Cycle Assessment (LCA) which is known as an effective technique. LCA identifies, quantifies and assesses utilized energy, material and waste released to the environment for a certain subject (whether it be product, process or activity) (Curran 2004).

LCA was initially presented by “Net energy analysis” study which considered only the amount of energy consumption over the life cycle of a product or a process in 1972 (Boustead 1972; Hannon 1972). Up to then, materials and energy’s quantification were not considered in LCA studies (Lundolm and Sundstrom 1985; Boustead 1989). LCA was completed in the 1990s by the works of Society of Environmental Toxicology and Chemistry and International Organization for Standardization as ISO 14040-3, after that ISO 14040 was revised in 2006 (ISO-14040 1997; ISO-14041 1998; ISO-14041 1998; ISO-14042 2000a; ISO-14043 2000b; ISO-14040 2006; ISO-14044 2006). However, the final version of the LCA standard with three main reductions in the number of standards, annexes and pages of the data requirements was presented in 2006 as ISO 14044 to improve the readability and accessibility of the standards (ISO-14040 2006; ISO-14044 2006). Moreover, the validity of the main technical content of the previous standards is reaffirmed in ISO 14040 and ISO 14044 also, the discrepancies and inconsistencies were decreased (Koroneos and Nanaki 2012). In 1999 Finnveden discussed some methodological issues in the LCA method in five sections including; a) system boundaries as upstream and downstream, b) open-loop recycling allocation, c) multi-input allocation, d) considering the time period, and e) life cycle impact assessment (Finnveden 1999).

Up to now, some articles reviewed most of the LCA application, investigating the usefulness of LCA methodology in SWM (Denison 1996; Finnveden and Ekvall 1998; Bjorklund and Finnveden 2005; Cleary 2009). LCA methodology has been used in many articles in recent years. Some of them are discussed below.

In 2003, Arena applied LCA methodology for the solid waste management in the south of Italy where the combination of RDF, biological treatment, thermal treatment and landfilling are considered as the evaluated scenarios (Arena and Mastellone 2003). Also, Hong utilized LCA for the municipal waste management in Pudong, China, based on the biological and mechanical treatment (Hong and Wang 2006). Bovea proposed his scenarios based on a combination of these elements: a) selective collection targets to be accomplished by the year 2015 as specified in the Spanish National Waste Plan, b) various national implemented collection models, c) diverse treatments of both the separated biodegradable fraction and the rest wastes are disposed of on landfills (Bovea 2010). Moreover, there are many similar articles that have defined various combinations of disposal methods such as recycling, RDF, composting, incineration and landfilling with or without gas recovery as their scenarios and assess the environmental impacts of wastes with the LCA methodology (Al-Salem and Lettieri 2009; Banar and Cokaygil 2009; Zhao and Wang 2009; Abduli et al. 2010; Hong et al. 2010; Koci and Trecakova 2011; Tunesi 2011).

Other methods are also applied to improve LCA modeling including; linear programming with Excel-Visual Basic (Abou Najm and El-Fadel 2004), decision supporting system (Fiorucci et al. 2003), fuzzy theory (Chang and Wang 1997; Vahidi et al. 2013) and multi-criteria decision making method (Hokkanen and Salminen 1997). In addition, in 2009 Cleary reviewed 20 LCA articles of MSW published between 2002 and 2008 (Cleary 2009). In this review article the utilized methodology, system boundaries, types of data sources, environmental impact categories, impact weightings, economic valuations, sensitivity analysis, and LCA computer models of 20 researches were evaluated and discussed.

In this article, LCA methodology is applied to model the municipal solid waste management in Tehran metropolitan. Tehran as the capital city of Iran has more than eight million inhabitants leading to 7507.5 tons/day waste generation. Most of the wastes (87%) are disposed in the Aradkouh landfill and the rest is composted (8.3%) or recycled (5%) (Abduli et al. 2010). Moreover, there are a few extra waste disposal facilities near Tehran such as biomechanical composting plant which have not been able to solve problems to an acceptable level (Abduli 1995). Until 1993, industrial wastes were also disposed in the Aradkouh landfill (Abduli 1996).Unfortunately, there are significant problems with the Aradkouh disposal site such as (Abduli 2002; Abduli and Safari 2003; Zand and Abduli 2008); (1) lack of gas emission control systems, (2) incompatibility of the imported technology with the local waste composition (in the case of composting units), and (3) seeping of leachate from landfilling and composting sites, which made a critical environmental situation in the nearby location. In addition, to investigate and improve the mentioned problems, a LCA study was applied in 2010 by Abdoli (Abduli et al. 2010). They focused on the two scenarios namely landfilling and landfilling plus composting (Abduli et al. 2010). On the other hand, there is a high potential in using recycling or incineration disposal system in Tehran and this can lead to present a wide range of solid waste disposal systems.

In this article, authors try to study various scenarios with different combinations of disposal options such as; recycling, composting, incineration and landfilling. In other words, more practical scenarios based on the combinations of the mentioned disposal methods are scrutinized to find the most proper one. In the following, all the utilized impact assessment standards, the applied model to calculate emissions and the definition of scope and boundaries are discussed.

Material and Methods

LCA methodology is used to evaluate the environmental performance of the waste management of Tehran for different scenarios, according to the ISO standards 14040 series 2006.

Goal and Scope definition

The aim of assessing LCA methodology for the municipal waste of Tehran is to investigate the possible environmental impacts of various solid waste management scenarios. It leads to the selection of the finest disposal system. The level of the decision makers' awareness would be increased according to the results of this research and leads to the possible reduction of the future undesirable environmental effects. It should be mentioned that, the collection and transportation of the waste from Tehran to Aradkouh due to similarity in all the scenarios are not mentioned.

Functional units

ISO 14040 standard defines the functional unit as ''the quantified performance of a product or system for use as a reference unit in a life cycle assessment study'' (ISO-14040 2006). In other words, the functional unit for ISWM should take into account the period of time for which the environmental impacts and waste generation are considered, based on the amount of waste and their composition (Bjarnadóttir et al. 2003). Therefore, for this study the functional unit has been chosen as the average amount of municipal generated waste of Tehran per day. The daily waste generation of Tehran (7507.5 ton/day in 2011) is considered as the input of the system. The amount and composition of Tehran’s waste collected and managed in Aradkouh is given in Table 1.

Table 1. MSW components and characteristics in Aradkuh Center (previously called Kahrizak)

Waste type	Mass (%)	Volume (%)	Mass (ton)
wet waste	67.8	26.4	5085
bread	1	2.7	75
soft plastic	2.2	14.8	165
hard plastic	0.6	4	45
PET	0.7	9.7	52.5
plastic bags	6.2	16.8	465
paper	4.4	4	330
paper(card board)	3.7	5.1	277.5
ferrous metals	1.6	1.1	120
non-ferrous metals	0.2	0.1	15
fabric (textile)	3.4	9.4	255
glass	2.4	2.2	180
wood	1.7	1.5	127.5
tiers	0.7	0.6	52.5
leather	0.6	0.4	45
dust & rubble	1.3	0.6	97.5
special waste (health care waste)	1.6	0.7	120
total	**100**	**100**	**7507.5**

System boundaries

Four different disposal systems including Landfilling, composting, recycling and incineration are selected as the main waste management processes. Each scenario is consistent of various combinations of these processes. Moreover, the unit, inputs and outputs of the processes in the system are defined as the system boundaries which are illustrated in the Figure 1. There are some assumptions to limit the scenarios such as; a) the Landfilling is considered without leachate and gas collection system, b) the total organic wastes are sent to the composting facilities, c) Glass, Aluminum, Iron and plastic wastes are used as the recycling materials and d) paper, wood, leather, plastic and textile wastes are gathered to burn in the incineration plant. These assumptions are based on the practical waste allocation and are essential to run the IWM model.

According to the various combination of the waste allocated to each disposal facility five scenarios are given in the Table 2. It should be mentioned that the waste allocation percentages in each scenario are based on the half and full consistency ability of the processes.

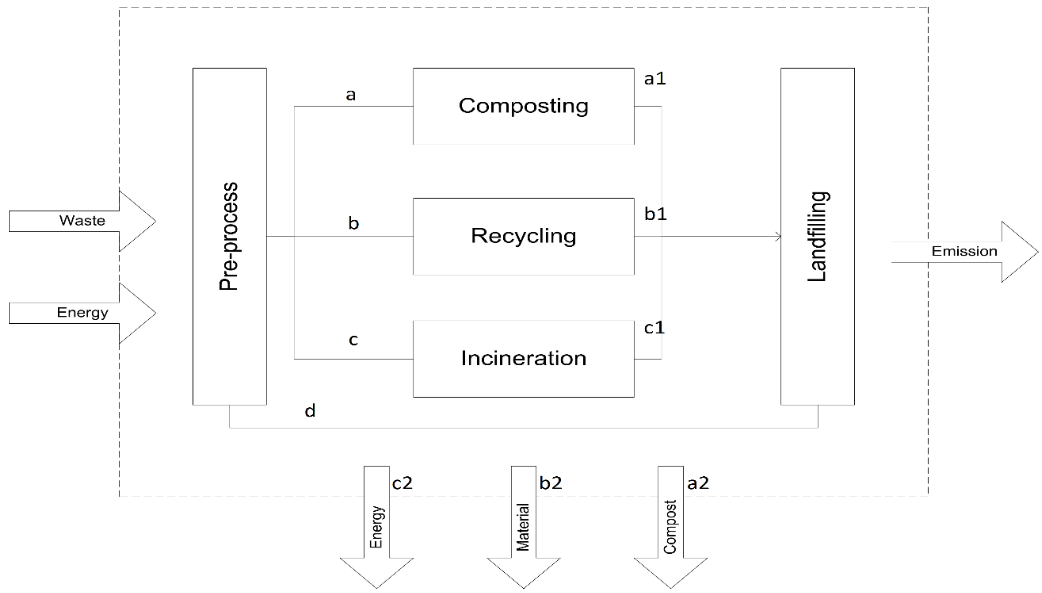


Figure 1. Flows of waste

Table 2. Disposal solid waste scenarios

Scenario	Compost (%)	Recycle (%)	Incineration (%)	Landfill (%)	Residue compost (%)	Residue recycle (%)	Residue incineration (%)	Final landfill (%)
	a	b	c	d	a1	b1	c1	
1	0	0	0	100	0	0	0	100
2	35	0	0	65	7	0	0	72
3	70	0	0	30	14	0	0	44
4	70	0	22	7	14	0	7	28
5	70	20	0	10	14	1	0	25

Data sources and quality

Data was collected from Tehran Municipality, Aradkouh composting facility, Tehran recycling organization and also by the interviews and site visit. As, the data is mostly official and gathered based on the scientific methods or statistical techniques in this study we do not discuss about the sources. Moreover, the data parameters used include a comprehensive range of factors due to the local conditions that would affect the performance of selected scenarios/waste management processes. The gathered information contains; the quality and quantity of the collected waste, characteristics of the disposal facilities, number of employees, distance between the facilities, energy consumption and land usage.Integrated Waste Management (IWM) software was used to estimate the emissions. The inventory results for the scenarios are shown in Table 3. In addition, Eco-indicator 99 was used to evaluate the impacts of emissions. Due to the uncertainties of the chosen impact assessment procedure, three different approaches namely; Egalitarian (E), Hierarchist (H) and Individualist (I) perspective were introduced in Eco-indicator 99 (PRé 2001). Different normalizing factors and weights for each procedure were applied. Hereupon, the Egalitarian and Individualist are focused more on the radical reality than the Hierarchist one, which due to its moderation Hierarchist is recommended as a default (PRé 2001; Cordella et al. 2008). So, Eco-indicator 99 in the Hierarchist perspective is utilized in this study.

Table 3. The inventory results of each scenario (per day)

Substances	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
			Air		
CO_2 (Kg)	-1645469	-975093	-304716	-1434559	711133
CH_4 (Kg)	323164	183451	43738	-15775	10161
NO_x (Kg)	102	163	223	-5310	1597
SO_x (Kg)	92	210	328	-4515	634
HCl (Kg)	29	16	4.6	-22959	232
PM (Kg)	2045	1920	1794	-484	1499
VOCs (Kg)	1029	691	352	-5750	334
Pb (kg)	0.007	0.013	0.019	-0.10	1.2
Hg (kg)	0.0001	0.0002	0.0004	-0.019	0.461
Cd (kg)	0.003	0.002	0.002	-0.004	0.121
Dioxins (TEQ) (g)	0.000	0.000	0.000	0.000	0.000
			Water		
Pb (kg)	0.49	0.38	0.26	-0.21	0.14
Hg (kg)	0.006	0.004	0.003	0.004	0.001
Cd (kg)	0.69	0.50	0.30	0.20	0.19
BOD (kg)	9290	6673	4055	3975	1967
Dioxins (TEQ) (g)	0.000	0.000	0.000	0.000	0.000

Due to Eco-indicator 99 methodology, 11 type of damages to human health, ecosystem quality; mineral and fossil resources are assessed as studied categories. Human health damages are assumed as the basic possible problems for human kind. Ecosystem quality assesses the acidification, euthrophication, ecotoxicity and regional/local effect on vascular plant species which are related to the drawbacks of disruptive changes of the non-human species' population and geographical distribution. Additionally, the measurements of the additional energy requirement to compensate the lower future ore grade are evaluated as the damage to mineral and fossil resources (Geodkoop and Spriensma 2001).

Briefly, the eleven impact categories to present the potential environmental impacts of the various solid waste management systems in Tehran are; a) Human health: carcinogenic, organic substances, inorganic substances, climate change, ionizing radiation and ozone layer depletion, b) Ecosystem quality: ecotoxic emissions, the combination of acidification & eutrophication and double coating, c) Mineral and fossil resources: extraction of minerals and the fossil fuels.

Results and discussion

The amount of emissions for each scenario is presented in Table 4 which is obtained from IWM model. IWM models various emissions including; greenhouse gases (CO_2 and CH_4), acid gases (NO_x, SO_x and HCI), smog precursors (NO_x, PM and VOCs) and heavy metals and some other pollutants (Pb, Hg, Cd and Dioxins) for both water and air environments. It should be mentioned that, the given data for the heavy metals and organics in Table 4 are the summation of both water and air amounts. Moreover, the emissions and damages for each scenario based on the Eco-indicator 99 are calculated and given in Table 5. In the next section the impact categories are discussed in details.

Table 4. Emissions and damages for the scenarios

Substances	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
			Air		
CO_2 (Kg)	-8967	-5314	-1660	-7818	3875
CH_4 (Kg)	36948	20974	5000	-1803	1161
NO_x (Kg)	280	447	614	-14578	4384
SO_x (Kg)	138	315	492	-6778	953
HCl (Kg)	0	0	0	0	0
PM (Kg)	19373	18183	16992	-4586	14198
VOCs (Kg)	17	11	5.9	-96	5.6
Pb (Kg)	1	2.5	3.7	-21	243
Hg (Kg)	0.008	0.01	0.02	-1	29
Cd (Kg)	12	11.2	9.6	-20	518
Dioxins (TEQ) (g)	0.71	0.40	0.09	0.000	5.6
			Water		
Pb (Kg)	0.28	0.22	0.15	-0.12	0.08
Hg (Kg)	0.10	0.07	0.04	0.06	0.02
Cd (Kg)	1319	948	577	394	373
BOD (Kg)	0	0	0	0	0
Dioxins (TEQ) (g)	4.8	3.5	2.1	1.3	1.3
Total	49129	35584	22039	-35308	25751

Table 5. Impact assessment results for the scenarios

Damage category human health	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Carcinogenic effects on humans	1309	942	576	371	799
Respiratory effects on humans caused by organic substances	124	72	20	-101	8.9
Respiratory effects on humans caused by inorganic substances	19739	18856	17974	-23213	18774
Damage to human health caused by climate change	27872	15599	3325	-9616	5034
Human health effects caused by ionizing radiation	2.77E-10	5.11E-10	7.45E-10	-4.21E-09	4.78E-08
Human health effects caused by ozone layer depletion	0	0	0	0	0
Total	49046	35471	21896	-32559	24617
Damage category ecosystem quality	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Damage to by ecotoxic emissions	30	23	17	-18	371
Damage by the combined effect of acidification and eutrophication	52	89	126	-2729	762
Double counting	17	8.6	3.7	1.7	1.8
Total	100	122	147	-2746	1136
Damage category resources	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Damage to resources caused by extraction of minerals	0	0	0	3405	0
Damage to resources caused by extraction of fossil fuels	1228	2918	4609	-195006	-18448
Total	1228	2918	4609	-191601	-18448

The energy consumption for each scenario due to the generation of IRAN's electricity specification is given in Table 6. These amounts which are considered as "from cradle to grave" are calculated by IWM software. Coal, natural gas, diesel, heavy fuel oil and hydro are known as the electricity sources and the proportion of each source is shown in Table 6. According to Table 7; scenarios 1, 2 and 3 consume energy especially natural gas whereas, scenarios 4 and 5 lead to save energy. However, scenario 4 saves natural gas, heavy fuels and diesel ten times more than the scenario 5. The amount of land occupation is estimated and presented in the Table 7. Scenario 1 with the 192.6 m^2/day needs the maximum area and scenarios 4 and 5 with 20 m^2/day need the least. Eco-indicator 99 was used to calculate the land used weights.

Table 6. Energy consumption

Energy	Percent of generation	Fuel needed					Weighted damage factor				
		Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Coal (Kg)	0.4	4.81E+01	1.14E+02	1.81E+02	-7.64E+03	-7.23E+02	2.88E-01	5.99E-03	1.08E+00	-4.58E+01	-4.33E+00
Natural Gas (m3)	72.9	7.02E+03	1.67E+04	2.63E+04	-1.11E+06	-1.05E+05	9.20E+02	1.31E-01	3.45E+03	-1.46E+05	-1.38E+04
Diesel & Light Fuel Oil (Kg)	8.2	6.88E+02	1.64E+03	2.58E+03	-1.09E+05	-1.03E+04	9.91E+01	1.44E-01	3.72E+02	-1.57E+04	-1.49E+03
Heavy Fuel Oil (Kg)	17.3	1.45E+03	3.45E+03	5.45E+03	-2.31E+05	-2.18E+04	2.09E+02	1.44E-01	7.85E+02	-3.32E+04	-3.14E+03
Hydro	1.2	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total	100	9211	2188	34561	-1462172	-13832	1.23E+03	4.25E-01	4.61E+03	-1.95E+05	-1.84E+04

Table 7. Land occupation

Land use	Land occupation per day (m^2)					weighted damage factor				
	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Landfilling	192	93	28	5.9	1.5	17	8.3	2.5	0.5	0.1
Composting	0	3.41	13.63	13.63	13.63	0	0.31	1.22	1.22	1.22
Incineration	0	0	0	0	5.30	0	0	0	0	0.48
Recycling	0	0	0	0.35	0	0	0	0	0.031	0
Total	192.61	96.85	41.97	19.89	20.44	17.28	8.69	3.77	1.79	1.83

Human health effects

Heavy metals and Dioxins are mainly responsible for carcinogenesis. Cd is found as the most effective heavy metal in this category. As can be indicated in Table 5, scenario 4 has the least carcinogenic effects on human's health, whereas scenario 1 with more than thrice this amount has the maximum effects. In addition, scenarios 2, 5 and 3 are chosen as the second, third and fourth damaging ones, respectively.

The drawbacks of organic substances on human health are mainly caused by the CH_4 and VOCs emissions. However, scenario 1 has the most effect on human health whereas scenario 2 with half amount of effects is placed in the second most harmful place. Scenarios 5 and 3 also have some damaging effects but much less than scenarios 1 and 2. But, scenario 4 due to recycling the organic substances has positive effects on the human health.

Inorganic substances including NO_x, SO_x and PM, have respiratory effects on human health where PM has the most damage. According to the Table 5, Scenarios 1, 2, 3 and 5 have negative impacts and their intensity varies equally with little fluctuation. In comparison, scenario 4 has positive impacts on human health which is mainly caused by recycling processes. In all the scenarios methane has the dominant effects on climate change, whereas Carbon Dioxide has the least effect. However, methane made the Landfill (mainly scenario 1) the most undesirable scenario among the others. Predictably, the amount of disposed waste in the landfill has a direct relationship to methane generation which leads to climate change. Therefore, scenarios 1, 2, 3 and 5 have the most negative impacts on climate change whereas, scenario 4 has positive impacts.

Pb emission in air leads to ionizing radiation in all scenarios. Scenario 4 has positive effect on human health caused by ionizing radiation but, in scenarios 1, 2 and 3 the impacts are very little or negligible. On the other hand, in scenario 5 due to the incineration damage production of Pb is by far the highest. So, scenario 5 is the most unpleasant one based on the ionizing radiation. In all the scenarios, ozone layer depletion is not allowed in the output of IWM model. Hence, no impacts on ozone layer depletion are assumed.

Ecosystem quality effects

Dioxins and Heavy metals including; Pb, Hg and Cd as both water and air emissions are the main reasons for ecotoxic hazardous impacts. Due to the high Cd concentration, it has the most effect among the mentioned heavy metals. However, scenario 4 improves the ecotoxicology of the system whereas other scenarios are harmful. Moreover, scenarios 1, 2 and 3 have little effects whereas scenario 5 has massive negative impacts on ecosystem quality which is significantly caused by the incineration facility.

Acidification and eutrophication are mainly caused by NO_x and SO_x, the effect of NO_x is more than SO_x. Additionally, scenarios 1, 2, 3 and 5 present negative impacts on the ecosystem quality. Scenario 5 has the maximum drawbacks due to the production of these gases during the burning process. On the other hand, scenario 4 has positive impacts on the ecology quality.

Scenarios 1, 2, 3, 4 and 5 require 192.6, 96.8, 42, 20 and 20 m^2 land area per day, consecutively. Based on the Eco-indicator 99, scenarios 4 and 5 with a relatively small difference to each other have the minimum effects on the land usage whereas scenario 1 has the maximum effects.

Damage to resources

There are positive impacts on the material recovery which are caused by the recycling of Iron and Aluminum. Hence, scenario 4 results in the recovery of significant amounts of raw material whereas other scenarios have no such effect.

Fossil fuels such as; Coal, natural gas, diesel (light fuel oil) and heavy fuel oil are considered to estimate the impacts on the resources. Scenarios 1, 2 and 3 have a little negative effect whereas scenarios 4 and 5 have positive ones. Moreover, scenario 3 has the maximum damage to resources whereas scenario 4 has the maximum positive effect.

Impact assessments of all scenarios on the human health, ecosystem quality and damage to the resource are illustrated in Figure 2. According to this Figure, scenario 1 has the maximum damage to the human health whereas scenario 4 has positive impacts. Also, scenarios 4 and 5 have advantages regards to the ecosystem quality but the other scenarios have little negative impacts.

Finally, scenarios 1, 2, 3 and 5 have negative effects on the resources whereas scenario 4 has the positive ones. To sum up, the life cycle assessment of the scenarios are shown in Figure 3 in which the final weights are calculated. It should be noted that the positive weights are presumed as drawbacks and the negative weights are assumed as a benefit. Therefore, based on Figure 3, landfilling with about 20% recycling and 70% composting (scenario 4) is selected as the most proper solid waste management system rather than the other scenarios. The final LCA weights of the scenarios 1, 2, 3, 4, and 5 are 50375, 38512, 38512, -233718 and 7304, consecutively.

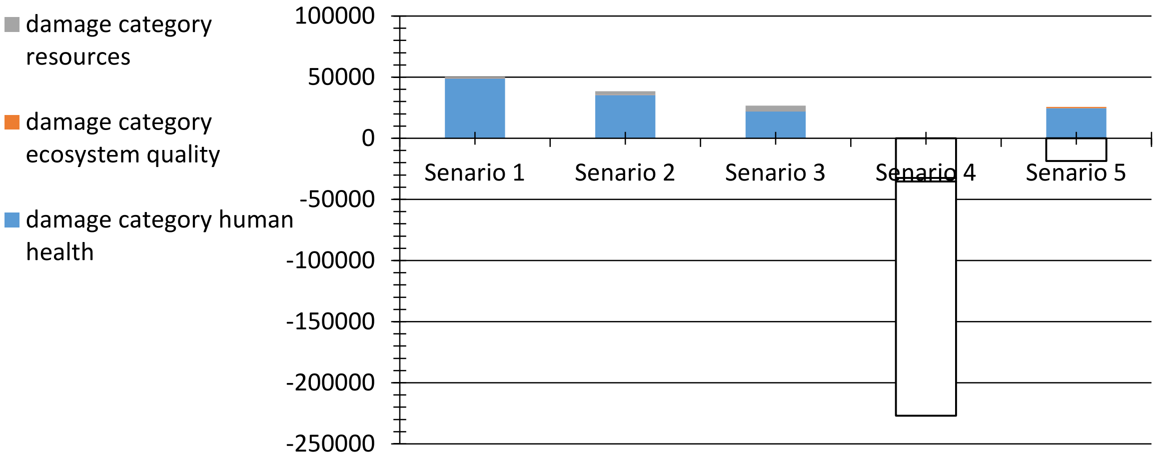
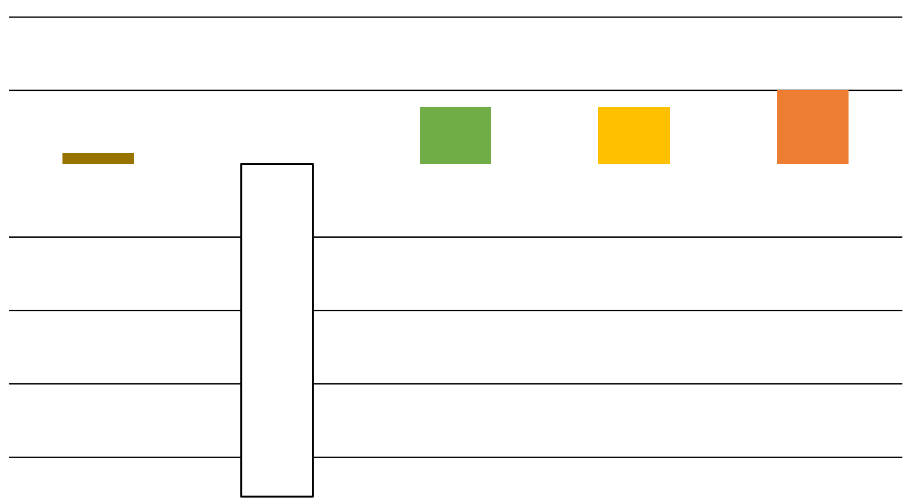


Figure 2. Weighted impact category values



	Scenario 5	Scenario 4	Scenario 3	Scenario 2	Scenario 1
LCA final weights	7304.94582	-226908.3576	38512.26911	38512.26911	50375.39966

Figure 3. Scenario's final weights

Conclusion

Among the different disposal methods for Tehran MSW such as; landfilling, composting, recycling and incineration, five combinations are selected as the solid waste management scenarios. Their environmental impacts are evaluated and compared due to the guideline of Eco-indicator 99 which is a damage oriented method for life cycle assessment.

This study shows that landfilling plus recycling and composting (scenario 4) has positive impacts on the human health, ecosystem quality and resources whereas other scenarios have less potential impact or even negative impacts. Scenario 1 has the most undesirable effects, mostly on the human health. In addition, scenarios 2 and 3 have negative impacts like scenario 1 but with less intensity. Scenario 5 causes damages on human health and ecosystem quality but it has positive effects on the resources.

According to the impact assessment of the scenarios, recycling, incineration, composting and landfilling seem to have more negative impacts on the environment, consecutively. In all scenarios methane and CO_2 have the main effects on air pollution. Scenario 5 emits the maximum CO_2 among the others which is undoubtedly caused by the incineration and burning process. Moreover, heavy metals including Cd and Pb show an extreme role in water pollution. Predictably, scenario 1 produces the maximum heavy metals as water emission. Although, scenario 4 produces heavy metals into the water environment it has a positive impact on Pb emissions. Scenarios 4 and 5 occupied less land area than the others and also they recover significant amounts of energy based on the IWM model. On the other hand, other scenarios lead to consume energy and need more land area. Finally, scenario four is highly recommended to be focused by the city authorities as the solid waste management system in Tehran.

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