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Life Cycle Assessment of Municipal Solid Waste Management System in Kathmandu, Nepal

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Abstract

Due to rapid urbanization, ever increasing population, limited resources and industrialization all-inclusive, the environmentally habitual management of municipal solid waste has become a global challenge. According to report of the National Population Census 2011, growth rate of Nepalese Population is 1.4 percent per annum with population density estimated at 181 per sq. KMs. Solid waste management in Nepal, the current practice of the illegal dumping of solid waste on the river banks has created a serious environmental and public health problem. The focus of this study was to carry out the magnitude of the present SWM problems by identifying the sources, types, quantities, dangers and opportunities they pose. It will be helpful to examine the adequacy of the existing institutional arrangements and implement a strategic and operational plan for SWM and to establish the EASEWASTE data base of municipal solid waste management system in Kathmandu City, Nepal.

Keywords: *EASEWASTE, Solid Waste Management, LCA, SWM*

1. Introduction

Due to limited resources, ever increasing population, rapid urbanization and industrialization the environmentally habitual management of municipal solid waste has become a global challenge. The urban population in industrialized country is 74% of the total population in those countries, whereas the urban population in developing nations accounted for 44% of the total 7 billion population of the world in 2011.However, urbanization is occurring rapidly in many less developed countries. It is expected that 70 percent of the world population will be urban by 2050, and that most urban growth will occur in less developed countries (UNPF).

Nepal is undergoing a population explosion in its urban areas in recent times especially due to rural

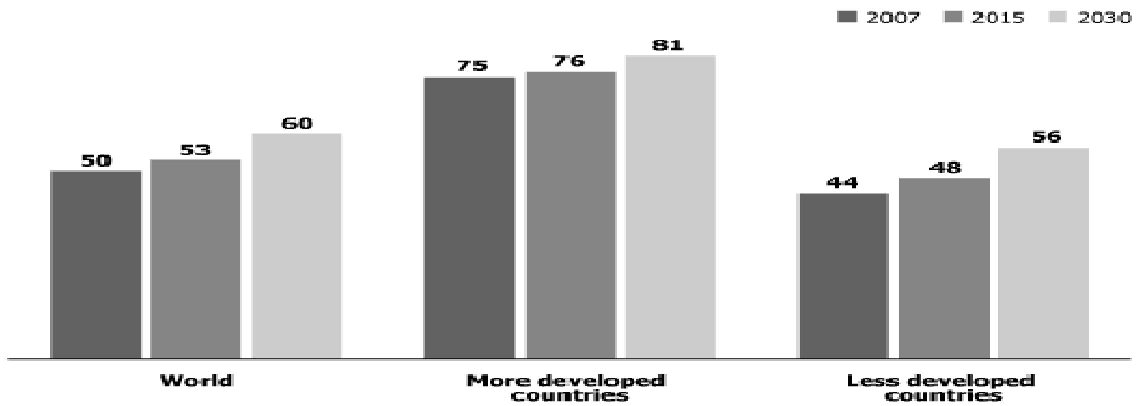


Fig 1 Percent of world urban population, 2007, 2015 and 2030(UNPF)

migrants seeking employment, business and other opportunities in the cities. The urban population of Nepal constitutes about 17 percent of the total population in 2011 compared to 14 percent urban population in 2001, which is low when compared with other developing nations. However, compared to the land area of the country and the available resources, this small urban population has become an enormous burden for the government in terms of environmental health, sanitation and environmental management.

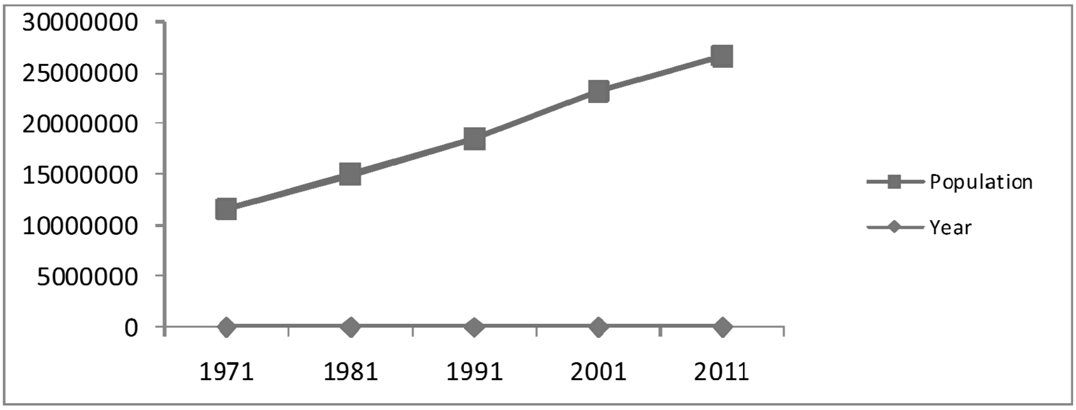


Fig 2 National populations according to censuses (CBS 2011)

Urbanization in Nepal is rapid and haphazard, creating problems in delivering services and facilities. Solid waste management has become a major challenge in most urban centers. Open waste piles are a common site and the work of municipalities' is often limited to sweeping the streets and dumping the waste in the nearest river or vacant land. The produced municipal solid waste (MSW) varies within Nepal and its municipalities. It is estimated that the total amount of municipal waste generated in Nepal is about 500,000 tons per year (Dangi, 2009).Solid waste was not such a big problem in the old days in the Kathmandu Valley. People in the Kathmandu Valley had their own method of managing their household waste, including circulation of organic waste between city and rural areas nearby. In line with increasing population in the Valley and changing life style and consumption habits, SWM has been increasingly recognized as one of the major environmental issues in the Valley as a result of the increasing amount of waste generated and the change of waste compositions. Gradually, the collection and disposal of solid waste started in some systematic way especially in KMC and LSMC, along with the operation of Gokarna Landfill (LF) which was developed in 1986. However, after closure of Gokarna LF in 2000 due to the opposition of the surrounding local people, final disposal could not stop going to river side dumping on a temporary basis, e.g. Bagmati River dumping

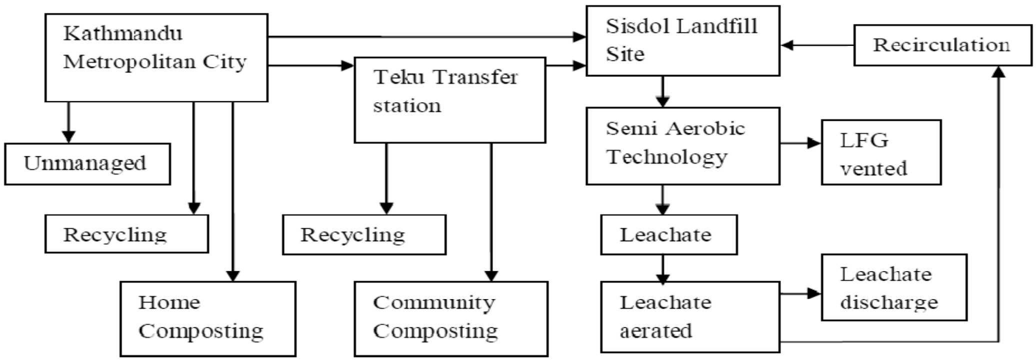


Fig 3 Solid waste management system of Kathmandu Valley

Leachate Treatment System:

The leachate collected in the pond is regularly aerated through proper aerator system, which can be regarded as biological aerobic treatment. The aerated leachate is further re-circulated by means of a pump to spray the leachate over landfill cells for a simple anaerobic biological treatment. The recirculation assists the waste to be more reactive and decompose faster than its normal rate. Hence, accelerating the rate of the methane and leachate production the Fig 4 below demonstrates the longitudinal profile of Leachate treatment plant.

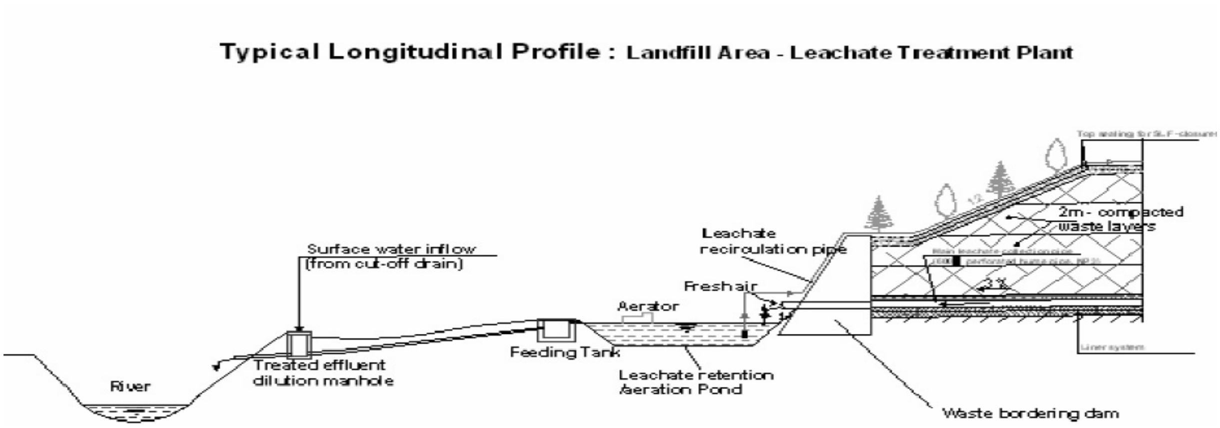


Fig 4 Leachate treatment plant in Sisdol landfill Site.

2. Methodology

For the Kathmandu case study, data have been collected mainly from Kathmandu Metropolitan City Office, Solid Waste Management and Resource Mobilization Center(SWMRMC), associated references and bibliographies. Some data which were unavailable were taken from the default database in EASEWASTE and it was utilized to represent a life-cycle inventory, a characterization of impacts and a normalized impact profile. System boundaries from the point of waste generation and source separation to the point after final disposal of the waste residuals are defined below with collected data and information.

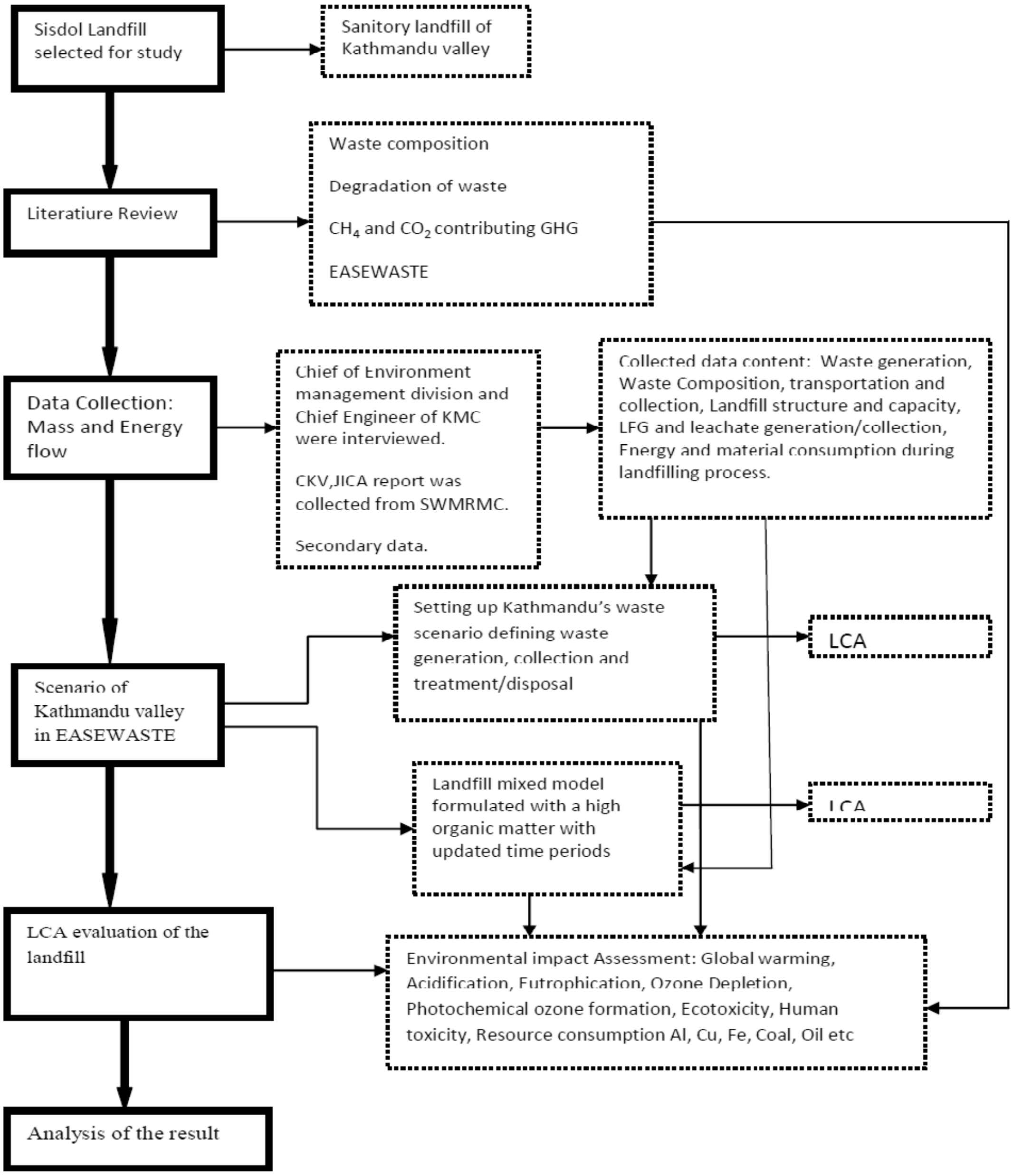


Fig 5 Flow chart of methodology

System Boundaries of the waste management system

Kathmandu is a metropolitan city located in the Central Development Region of Nepal and approximately 2,20,000 inhabitants lived in the City of Kathmandu in 2009, (Pradip Raj Pant).The housing is dominated by two to three storied multi-family Houses. The unit generation rate of waste was 0.4 kg per person per day, and the total amount of municipal solid waste was approximately 400 tons per day (KMC).The composition of solid waste used in this research is shown in the Fig 6.

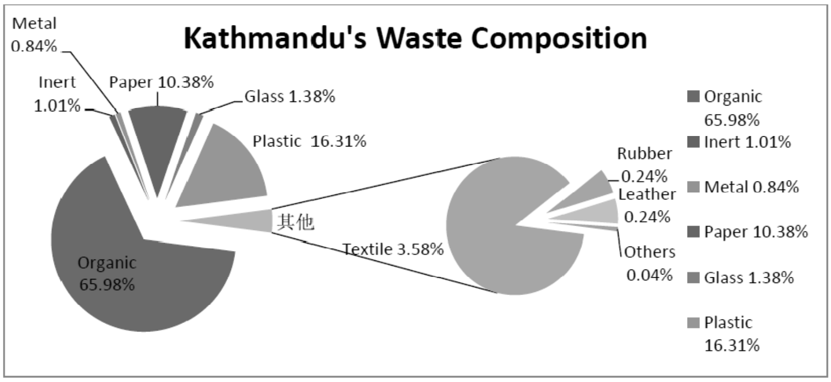


Fig 6 waste composition of Kathmandu valley(source: KMC 2001)

The total amount of solid waste was 146,000 tons per year, of which 96,360 tons per year was Organic waste which was individually collected from door to door, including 16,060 tons per year of waste paper, 24,820 tons of waste plastic, 1898 tons of waste glass and so on. The sorting efficiencies of the recycled materials of the waste including plastics, paper, and glass were assumed as 20%, 60% and 80% respectively. The integrated solid waste system of the city is represented in the Fig 7.

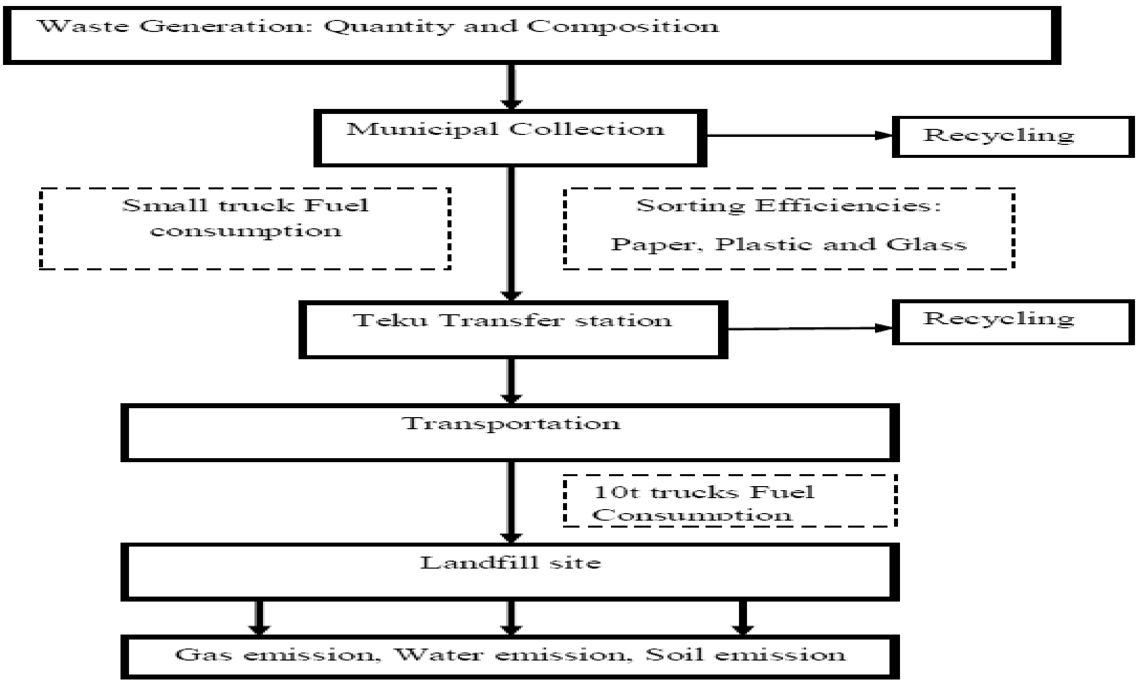


Fig 7 Municipal solid waste flow of Kathmandu City, Nepal (KMC)

Scenarios

The environmental assessment was based on three scenarios, in which the first two (scenarios 1 and 2) addresses the landfill treatment technologies and scenario 3 assesses the environmental impacts from composting all the organic matters generated from households of Kathmandu.

Scenario 1 is the current waste management system in Kathmandu, in which the mixed waste after recycling is sent to the landfill where land fill gas (LFG) emissions are not treated.

Scenario 2 is based on utilizing the LFG generated from the landfill for electricity production. All the data is exactly the same with scenario 1 except in scenario 2 the LFG is recovered and utilized.

Scenario 3 considers all the Organic waste generated from Kathmandu City is sent for composting and the remaining waste is sent to the landfill.

3. Result and Discussion

The results for all three scenarios were calculated as normalized potential impacts according to the normalized environmental impacts potential reference of Life Cycle Inventory Assessment (LCIA) method, EDIP 1997 (Wenzel et al. 1997). Normalization provides a relative expression of the environmental impact or resource consumption compared to the impact from one average person.

3.1 LCA evaluation of Kathmandu's waste with and without Electricity production:

Figure 8 shows the non toxic environmental impacts caused by scenario 1 where it can be seen that the highest impacts during 100 year period are on Global Warming and Stratospheric Ozone depletion. The major contribution (direct impact) is due to disperse emissions (through landfill gas) of CH4 and CFC12. The total quantity of CO2-eq substances emitted that caused Global Warming is 249,148.724 kg per year with reference to EDIP97

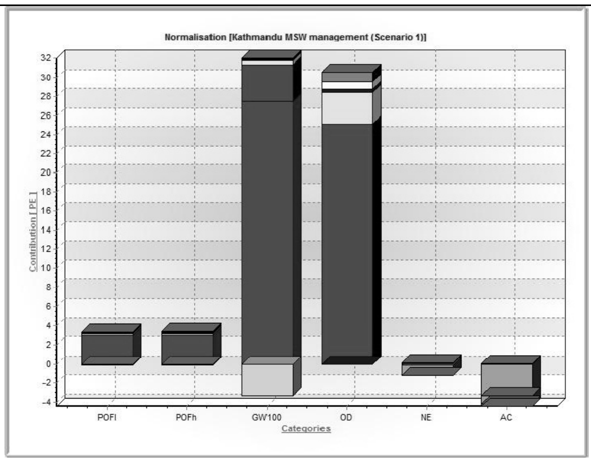


Fig 8 Normalized potential impacts for scenario 1

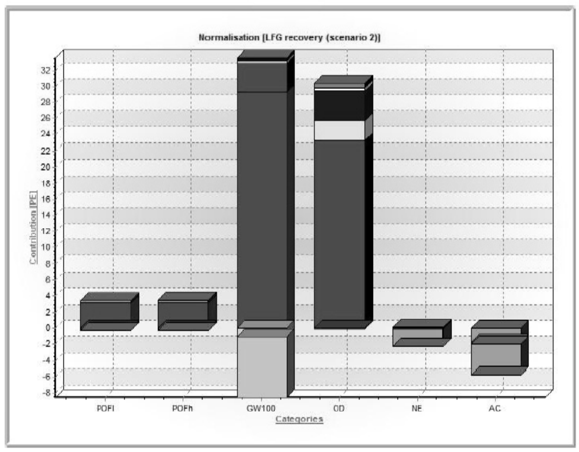


Fig 9 Normalized potential impact for scenario 2

The Fig 9 shows the non toxic environmental impacts caused by scenario 2 that has more or less similar trend of the impacts as of scenario 1. The figure 10 displays the compared graph of scenario 1 and scenario 2. In all the impact categories, scenario 2 i.e. the landfill with LFG recovery system demonstrated the better result than scenario 1, without LFG recovery. The total amount of non toxic environmental impacts of both the scenarios, are demonstrated in the table 1

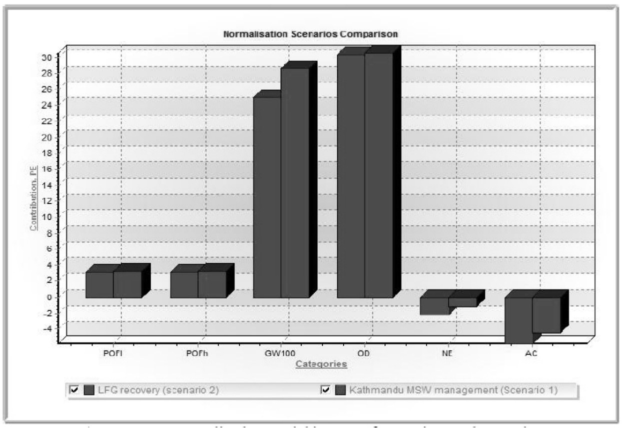


Fig 10 Normalized potential impact of scenario 1 and scenario 2

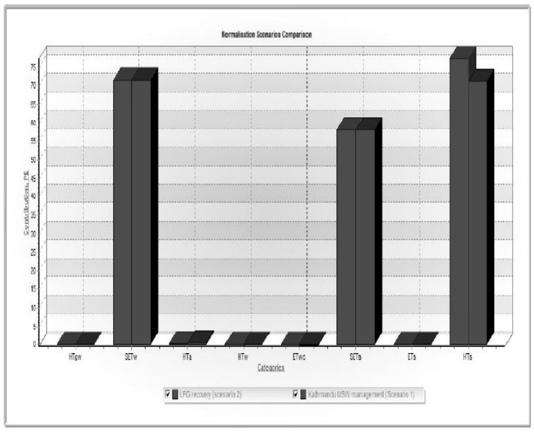


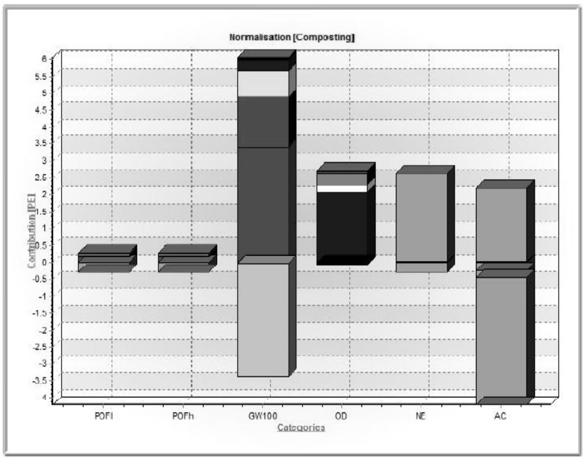
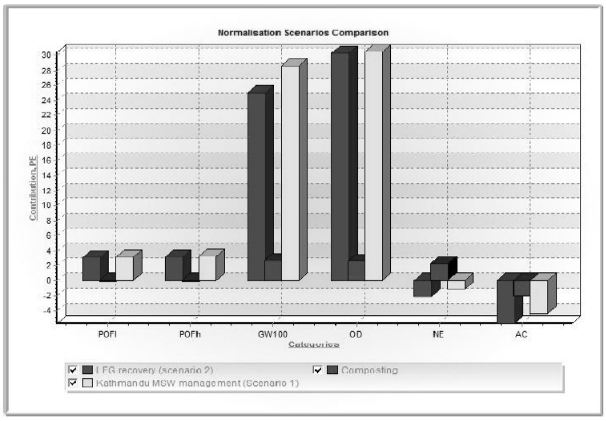
Fig 11 Normalized potential impact of scenario 1 and scenario 2(toxic)

Table 1 Environmental Impacts (toxic) of scenario 1 and 2

Photochemical Ozone Formation, Low NOx (EDIP97): [kg C2H4-eq]	Photochemical Ozone Formation, High NOx (EDIP97): [kg C2H4-eq]	Global Warming 100 Years (EDIP97): [kg CO2-eq]	Stratospheric Ozone Depletion (EDIP97): [kg CFC11-eq]	Nutrient Enrichment (EDIP97): [kg NO3-eq]	Acidification (EDIP97): [kg SO2-eq]
80.282	81.586	249,148.724	3.144	- 133.028	- 327.64
79.035	80.793	215,875.606	4.258	- 308.462	- 469.521

3.2 Environmental Assessment of Composting compared with Landfill with and without Recovery

Figure 11 shows environmental impacts caused by scenario 3, the scenario where all the organic contents of the city is assumed sending for composting instead of land filling. The impact on Nutrient enrichment is high due to high quantity of Ammonia (NH3) and Phosphate (PO4) discharged from composting. Emission of 23,246 kg of CO2-eq contributes to the impact on Global warming which is 90% less than the actual scenario of Kathmandu City and 75% from scenario 2.

 Fig 12 Normalized Environmental impacts of scenario 3	 Fig 13 Normalized environmental impacts of Scenario1, scenario 2 and scenario 3

The fig12 demonstrated that composting scenario was regarded as one of the best alternatives for the management of solid waste according to the Life-Cycle perspective. Impact on Global warming is significantly reduced by 91.6% compared to scenario 1 and 91.4% compared to scenario 2 because reduced amount of CFCs were generated from the landfill due to the absence of Organic waste.

Table 2 Comparison of scenario 1 and scenario 2

Impacts	Scenario 1 PE	Scenario 2 PE	Difference in PE	Remarks
Global Warming	28.638	25.018	-3.62	Scenario 2 is marginally better than scenario 1
Photochemical Ozone formation	3.263	3.177	-0.086	Scenario 2 is marginally better
Stratospheric zone deplation	30.523	30.247	-0.176	Marginal difference
Nutrient Enrichment	-1.118	-2.128	-1.01	Scenario 2 is better than scenario 1
Acidification	-4.428	-5.77	-1.342	Scenario 2 is better than scenario 1

Table 3 comparison of scenario 2 and 3

Impacts	Scenario 2 PE	Scenario 3 PE	Difference in PE	Remarks
Global Warming	25.018	2.672	-22.346	Scenario 3 is significantly better than scenario 2
Photochemical Ozone formation	3.177	-0.007	-3.184	Scenario 3 is significantly than scenario 2
Stratospheric Zone deplation	30.247	2.626	-27.721	Scenario 3 is significantly better
Nutrient Enrichment	-2.128	2.359	-4.487	Scenario 2 is better
Acidification	-5.77	-1.118	-6.88	Scenario 2 is better

3.3 Life Cycle Assessment of the landfill with LFG Recovery

This scenario describes the assumed scenario of Kathmandu city where the landfill is equipped with electricity generation system. The resources consumed in this scenario were fewer than that of the actual scenario of Kathmandu. Water cooling was again a major raw material that was consumed for cooling the engines of the vehicles. 1330 kg of water was needed for cooling the engines of the vehicles. Natural gas was consumed in a lesser amount than that of Kathmandu's real scenario, i.e. only 4.782E-6 kg of gas was used per ton of waste. Similarly, other substances like Calcium Chloride, Iron, and Aluminum ets were used along with clay and soil for the liner and daily cover respectively. Due to the production of electricity almost 12 to 15 percent methane is reduced causing less Green house effect resulting in less impact on global warming than in the actual scenario.

3.4 Analysis of Life Cycle Assessment of three scenarios: Landfill without LFG recovery, Landfill with LFG recovery and Composting of Organic waste.

When all the Organic waste is composted instead of sending it to the landfill, only 2 liters of fuel is combusted per day using only 0.3 Kwh of electricity whereas 6 liters of fuel is used up for the scenario 1 and scenario 2. The electricity consumption for the landfill with electricity generation technology is highest than other scenarios due to the use of electricity for generators. The collection and transportation vehicles are very few in number, for composting, resulting in less consumption of fuel. Therefore, in the sector of energy consumption, composting the Organic matter, which covers the large content of waste i.e. ~70%, is the best alternative for Kathmandu City. According to the Life Cycle Assessment, Water is the major raw material that has been consumed in all of the three scenarios. Collection and transportation phases are the main area where water was consumed for the cooling purpose. Comparatively, less amount of water was consumed for composting scenario. Likewise, Natural gas was consumed in similar amount for the actual scenario of Kathmandu and the scenario where all the organic waste is composted. When compared between three scenarios, scenario of the Kathmandu where the waste is dumped into the landfill with electricity generation, consumed very less raw materials. Therefore, in the sector of raw material consumption, it can be analyzed that, landfill with electricity production is best for consuming less amount of raw materials. Methane is the major emission mainly dependent upon the composition of the solid waste and partially to the collection and transportation phase. Since, all the Organic waste is send for composting in scenario 3, the methane is mostly generated from the remaining waste and the collection and transportation phase. When the waste is dumped to the landfill with the energy recovery system, 14% of methane was reduced than the landfill without energy recovery hence proving to impact less on Global warming. According to the LCIA 80% of the heavy metals come from organic waste and remaining from the inorganic waste.

4. Conclusion

The results from the environmental assessment of the solid waste system in the City of Kathmandu showed that the Landfill Gas Recovery from the landfill and utilizing the Gas for Electricity production is relatively better than the current system, mainly due to the lowering of Green House Gases such as Methane, CFCs etc while the increasing in energy production from waste. The organic content of the Kathmandu city is very high, which means that more the organic matter higher the amount of methane, likewise, higher the amount of methane, more the generation of electricity. Therefore, the energy recovery system will give the city advantage from both the sides; lower the emissions of Green house gases and utilization of electricity.

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