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# Life Cycle Assessment of Municipal Solid Waste Management System in Kathmandu Metropolitan City

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**Abstract**— The study was focused on the life cycle assessment of the municipal solid waste management of Kathmandu Metropolitan City (KMC). One ton of waste was taken as a functional unit to compare different scenarios. Scenario 1: business as usual includes collection, transport and landfilling, Scenario 2: energy recovery with recycling and Scenario 3: conjunctive disposal system comprising of composting and landfilling. The life cycle inventory was developed that includes detail unit process and has quantified values of various resources and emissions to environment were calculated as Global Warming Potential (GWP), Acidification Potential (AP), Eutrophication Potential (EP) and Fuel Energy Consumption (FEC). GWP, AP, EP and FEC were calculated for the each scenario and compared in kg equivalents per tones of waste managed in landfill. The GWP for scenario 1 was approximately 3 times more than GWP for scenario 3, while the AP, EP and the FEC was almost same as GWP. In accordance with the results, scenario 3 was found to be the option with minimum environmental impacts (less GWP, AP, EP) and cheap in case of fuel consumption cost. The result is influenced more due to hi gher composition of organic waste that can be composted and the GWP can be controlled by it. The final results obtain from this study can be applied for the integrated solid waste management system as an environmental tool.

**Index Terms**— Acidification, Eutrophication, Global Warming Potential, Life cycle Assessment (LCA), Life Cycle Inventory (LCI)

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## 1 Introduction

MUNICIPAL Solid Waste (MSW) generation rates are increasing rapidly in Asian countries as a result of accelerated urban population growth, unplanned urbanization and increasing economic activities and resources consumption. And the solid waste management systems in many developing countries in Asia are not so satisfactory [1]. As a capital city of a developing country the rapidly urbanizing Kathmandu Metropolitan City (KMC) is facing the difficulties regarding the Municipal Solid Waste Management (MSWM).

KMC has a population growth rate almost 3.4 times the national rate, from 2001 to 2011, Nepal's national population grew by 1.4% per year while KMC's population increased at 4.76% year [2] which creates an unprecedented stress on city's limited resources and infrastructure creating MSW management problems [3]. Researchers argue that a complex issue due to the changing life styles of people, under-estimated contributors and stakeholders [4]. The solid waste management in KMC is facing the improper management. Since it's the responsibility of the city authority, the tendency of them is to seek the solution by attributing the SWM largely as an engineering function. The scenario in KMC is comparable with other least developed Asian Country Cities.

According to Census 2011, the population of KMC is over 1 million and the average unit generation of solid waste in KMC is 0.3 kg/person/day. The daily waste generation from the different sources was found as 480 ton/day at the end of 2011. The table 1 shows the data of the waste sources and corresponding quantities.

Among this organic waste comprises the 63.22% of the total waste; plastic comprises 10.8% of total waste while least is metal which comprises 0.42% of total municipal waste. The collection rate is 96% while 4% remain uncollected.

The municipal solid waste generated also has several impacts on environment and has contribution to global climate change [5]. Regarding the rate of waste production and its composition, different alternatives might be used for waste management systems. The LCA can be used as an environmental assessing tool for comparing and analyzing of the environmental impacts of the solid waste management systems [6]. Hence a number of studies in the literature used LCA as a comparative tool for different MSWM schemes ([7], [5], [8], and [9]). The purpose of this study was to use LCA as a tool to compare the three different SWMS options and determine the most feasible and environmental friendly system for KMC. For this three different scenarios were developed and then compared with respect to their environmental impacts and fuel cost using the Integrated Waste Management model [8].

This study was focused on comparison of the scenarios to give sustainable alternatives and assessment of consequences of different structures settled in the process of MSW management.

The figure 1 shows the composition of the municipal solid waste of KMC.

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TABLE 1
GENERATION OF WASTE FROM DIFFERENT SOURCES [10]

| S.N. | Sources | Quantity (ton/day) |
|---|---|---|
| 1. | Household Waste | 330 |
| 2. | Commercial Waste | 50 |
| 3. | Street Waste | 50 |
| 4. | Waste from Nearest VDCs | 50 |
| | TOTAL | 480 |

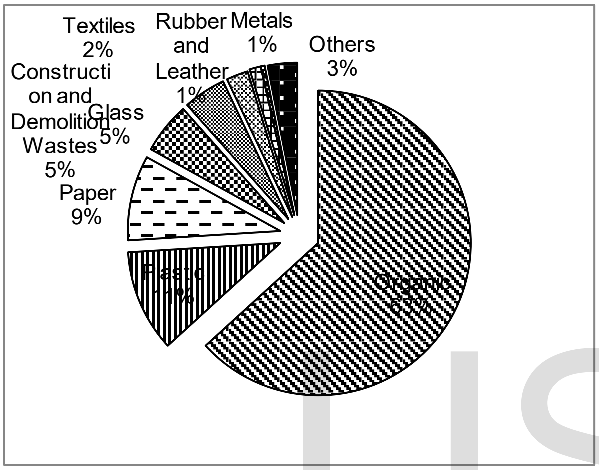


Fig. 1. Composition of Municipal Solid Waste of KMC.

## 2 METHODOLOGY

### 2.1 Life Cycle Assessment (LCA)

According to ISO 14040 [11], LCA consists of four phases performed in an iterative manner. These phases are: Goal and Scope definition, which serves to define the purpose and extent of the study to indicate the intended audience and to describe the system to be studied as well as options will be compared. Inventory analysis or the Life Cycle Inventory (LCI) focuses on the quantification of mass and energy fluxes. Life Cycle Impact Assessment or LCIA, which aims at the understanding and evaluating the magnitude and the significance of potential environment impacts of a system [12]. Interpretation, evaluates the result from the previous phases in relation to the goal and scope in order to reach the conclusions and recommendation [13].

### 2.2 Scope and Goal Definition

Three different scenarios of Municipal Solid Waste Management System (MSWMS) that include different MSW processing and/or disposal methods were developed, and then compared with respect to their environment burdens like Global warming potential (GWP), Acidification potential (AP), Eutrophication potential (EP) and total Fuel Energy Consumption. The scenarios were based on the current system of Municipal Solid Waste Management of Kathmandu Metropolitan City.

### 2.3 The Functional Unit and System Boundaries

The functional unit in this study has been defined as the total amount of waste generated in KMC in a year, i.e. Household, Commercial, Street and Nearest VDCs equal to 168,265 tons as per total collection of solid waste.

The functional system boundaries selected for this LCA is it only includes the direct emission from the waste after landfill where waste was defined as the moment when material ceases to have value, evidently considered as waste.

### 2.4 The Scenarios

The three scenarios considered in this study with system boundaries are illustrated in figure 2. The scenario 1 is *Business as Usual (BAU)* which includes collection, transport and landfilling, which is the current status of MSW undertaken by KMC. A very small fraction of waste is recovered as recycled materials are not considered here. The scenario 2 is *Energy Recovery* with recycling where the recyclable waste are recovered and recycled while remaining the wastes is landfilled. This scenario is fed in the model in order to assess the possibility of improving the current MSWS of KMC. And the scenario 3 is *Conjunctive Disposal System* comprising of composting and landfilling which employs aerobic and anaerobic digestion before landfilling.

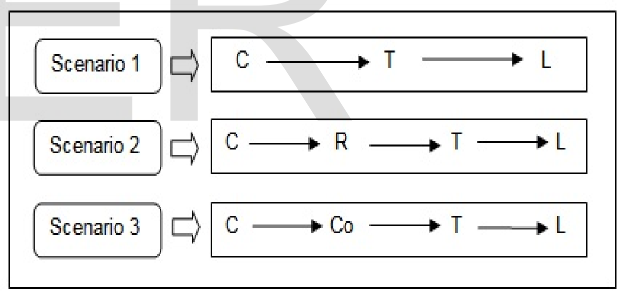


Fig. 2.Three different scenarios used in this study.
Note: C: Collection, T: Transportation, L: Landfilling, R: Recycling, Co: Composting

### 2.5 Life Cycle Inventory (LCI)

The data used in this study was collected from the sole tion that is responsible for the waste management in Kathmandu Metropolitan City i.e. The Environment Management Department and Solid Waste Management Section in 2011 AD. The data used were population of KMC, waste characteristics, waste collection rate, composition by weight and operational data of landfill site of KMC. The data were fed to the model, including % landfill input, processing capacity, composting rate, recycling rate, diesel fuel consumption cost (NRs/ton consumed) and distance to landfill site (km).

### 2.6 Life Cycle Impact Assessment

In any LCIA result of life cycle inventory, the objective of the study is converted to the managerial forms which are to be achieved. To perform the LCIA, the methodology and the standardization used does not have the global acceptance because the necessary data regarding the MSWM does not exist. And the scientific methods for the long time assessment are not presented [5]. The approach of the "Lower is Better" has been used since 1990s and assumed that all values from one type of stress are gathered together without considering the place and time of stress and due to their characteristics that may cause harmful changes in environment [14].

### 2.7 Interpretation

This final stage of LCA includes the reviewing of all the stages of LCA. Comparative analysis was also carried out using MS-Excel™ 2007. The results were backed up with the proper justification and reasoning.

## 3. Result And Discussion

### 3.1 Figures and Tables

The scenario based on the data was gathered at the life cycle inventory stage. The table 3 shows the amount landfilled, the amount of waste generated per year, waste that can be used for composting and the amount of waste that can be recycled in each of the scenarios. The scenario 1 represents the Business as Usual where landfilling is the only option for disposal that exceeds the 168,265 tons of waste annually. The waste that can be recycled in scenario 2 is 39,930 tons per year. The organic waste that can be used for composting is 106,360 tons. The organic waste is more than 60 % of the total municipal waste of KMC (see figure 1).

### 3.2 Quantifaction of Environmental Impacts

TABLE 2
Amount (Gg/year) landfilled, that can be recycled and that can be used for composting in each of the developed scenarios

| Scenario No. | Amount of MSW landfilled (Gg/yr) | Amount of Waste that can be recycled (Gg/yr) | Amount of Waste that can be used for composting (Gg/yr) |
|---|---|---|---|
| 1 | 168.26 | - | - |
| 2 | 128.33 | 39.93 | - |
| 3 | 61.90 | - | 106.36 |

1 Gg = 1,000,000,000 gm

*Global Warming Potential*: Based on the characteristics and conditions, IPCC default values for Sisdole Landfill site i.e. deep and unmanaged dumping site, different factors estimated the total potential methane generation from 1 tonne of waste is 29 kg of $CH_4$ [15]. And the conversion factor for kg $CO_2$ equivalent for 1 kg $CH_4$ is 21 [16].

*Acidification Potential*: According to Nielsen and Hauschild landfill model [17], it was estimated that 0.65 kg of $H_2S$ is emitted from 1 tonne of waste landfilled. The overall acidification potential is estimated to be 1.22 kg $SO_2$ equivalents per tonne waste landfilled as per the data given.

*Eutrophication Potential*: Nitrogen is a major substance in waste and the key contributor for the eutrophication potential. The estimated eutrophication potential for one tonne of waste is 16.42 kg of $NO_3^-$ equivalent [9].

*Fuel Energy Consumption for operation*: According to the data provided by KMC, the total fuel cost including diesel and petrol for the collection, transportation and management of the waste for fiscal year 068/069 is approximately NPR. 745,251.00. This means KMC spends NRs. 4.42 /tonne of waste transported and landfill as fuel cost.

TABLE 3
Comparison of the Scenario results

| Scenario No. | GWP (Kg $CO_2$ eq. per waste managed in landfill per year) | AP (Kg $SO_2$ eq per waste managed in landfill per year) | EP (kg $NO_3^-$ eq per waste managed in landfill per year) | EC (Total consumed operating fuel (NRs/ waste managed in landfill per year) |
|---|---|---|---|---|
| 1. | 102.47E+06 | 20.52E+04 | 27.62E+05 | 745,251.0 |
| 2. | 78.15E+06 | 15.65E+04 | 21.01E+05 | 567,240.7 |
| 3. | 37.69E+06 | 7.55E+04 | 10.16E+05 | 273,620.1 |

GWP: Global Warming Potential; AP: Acidification Potential; EP: Eutrophication Potential; EC: Energy Consumption for transportation and management of waste from transfer station to landfill.

## 4 Conclusion

This study was carried out to determine the best suitable and sustainable municipal solid waste management system out of the three given scenarios developed for the KMC. This was executed by using the LCA as a tool to compare different options. The main findings are of the study done are described in following points:

- The current practice which is scenario 1 it has highest GWP which contributes to climate change and considered bad in terms of other environmental impacts too.
- The scenario 3 is best with regards to GWP, EP as well as FEC.
- Scenario 2 was with medium environmental impacts unlike the higher scenario 1 and lower scenario 3.

According to the results obtained, scenario 3 was found to be the option with minimum environmental impacts (less GWP, AP, EP) and cheap in case of fuel consumption cost. As well the result is influenced more due to the higher composition of the organic waste that can be composted and the GWP can be controlled by it. The final results obtain from this study can be applied for the integrated solid waste management system (ISWMS) as an environmental tool.

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## References

[1] Visvanathan, C., Trankler, J., Joseph, K., Chiemchaisri, C., Basnayake, B. & Gongming, Z. (2004) Municipal solid waste management in Asia. Asian Research Program on Environmental Tchnology (ARRPET).

[2] CBS (2010) *Statistical Pocket Book Nepal 2010,* Kathmandu, Central Bureau of Statistics, Government of Nepal.

[3] Dangi, M. B., Cohen, R. R. H., Urynowicz, M. A. & Poudyal, K. N. (2009) Searching for a way to sustainability: technical and policy analyses of solid waste issues in Kathmandu *Waste Management and Research,* 27**,** 295 - 301

[4] Jha, A. K., Singh, S. K., Singh, G. P. & Gupta, P. K. (2011) Sustainable municipal solid waste management in low income group of cities. *Tropical Ecology,* 52**,** 123-131.

[5] Tabata, T., Hishinuma, T., Ihara, T. & Genchi, Y. (2010) Life cycle assessment of integrated municipal solid waste management systems, taking account of climate change and landfill shortage trade-off problems. *Waste Management & Research,* 29**,** 423 - 432.

[6] Khorasani, N., Naghibzadeh, S., Ghadiryanfar, M. & Badehian, Z. (2012) Life Cycle Assessment (LCA) of Municipal Waste Management System of Karaj. 41 – 45.

[7] Al-salem, S. M. & Lettieri, P. (2009) Life Cycle Assessment (LCA) of municipal solid waste management in State of Kuwait. *European Journal of Scientific Research,* 34**,** 395 - 405.

[8] Stypka, T. (2002) Adopting the integrated waste management model (IWM-1) into the decision process. Institute of Heat Engineering and Air Protection, Cracow University of Technology.

[9] Menikpura, S. N. M., Gheewala, S. H. & Bonnet, S. (2012) Sustainablility assessment of municipal solid waste management in Sri Lanka: problems and prospects *J Mater Cycles Waste Management,* 10.

[10] KMC (2011) Basic fact sheet of Solid Waste Management of Kathmandu Municipal Corporation IN SECTION, S. W. M. (Ed.). Kathmandu, Kathmandu Metropolitan City.

[11] ISO (2006) ISO 14040 international standard *Environmental Management -* life cycle assessment - principles and framework**,** International Organization for Standardization, Geneva, Switzerland.

[12] Clift, R., Doig, A. & Finnveden, G. (2000) The application of life cycle assessment to integrated solid waste management. *Trans IChemE,* 78**,** 279 – 287.

[13] Assamoi, B. & Lawryshyn, Y. (2011) The environmental comparison of landfilling vs. incineration of MSW accounting for waste diversion. *Waste Management,* 32**,** 1019 - 1030**.**

[14] White, P. R., Franke, M. & Hindle, P. (1997) *Integrated Solid Waste Management - a Lifecycle inventory,* London, Blackie Academic and Professional.

[15] UNFCC (2008) Methodological tool - Combined tool to identigy th baseline scenario and demonstrate additionally. *CDM - Executive Board*

[16] DEFRA (2012) 2012 Guidelines to DEFRA / DECC's GHG Conversion Factors for Company Reporting. Department of Energy and Climate Change (DECC) and the Department for Environment, Food and Rural Affairs (DEFRA).

[17] Neilsen, P. H. & Hauschild, M. (1998) Product specific emissions from municipal solid waste landfills. Part I, Landfill Model. *International Journal of Life Cycle Assessment,* 3**,** 158 – 168.