M. Alamgir, S.M.T. Islam and J. A. Saju (Eds.)
ISBN: 978-984-35-4034-8

Proceedings of the Waste Safe 2023 – 8th International Conference on Integrated Solid Waste and Faecal Sludge Management
25-26 February 2023, Khulna, Bangladesh

LIFE CYCLE ASSESSMENT OF MUNICIPAL PLASTIC WASTE MANAGEMENT IN KATHMANDU

Ramesh Khanal* and Bibhuti Ojha*

*Nepal Engineering College, Bhaktapur, Nepal

ABSTRACT

Municipal solid waste management (MSWM) in developing and underdeveloped countries is just limited to collection, transportation, and disposal of solid wastes. Among various disposal options, landfilling is still the most popular method of disposal since it is the easiest and most cost-effective. Among the various municipal solid waste (MSW) types, management of plastic waste has been challenging. It is advised to create integrated solid waste management plans that take into account the waste hierarchy as well as technical, environmental, economical, cultural, institutional, and political factors. One of the tools that account for the environmental factor is Life Cycle Assessment (LCA). So the study is aimed to apply LCA to know the extent of impacts due to MSWM practice in Kathmandu, Nepal. Two scenarios are developed; first, existing SWM practice (baseline scenario) and second - intervention in existing scenario by segregating plastic waste at source (alternative scenario). Both scenarios are modeled in OpenLCA1.11 platform using ELCD datasets and ReCiPe 2016 Midpoint (H) methodology. It is found that the baseline scenario was found to have the greatest impact across all impact categories. According to sensitivity analysis, there are increased environmental benefits when segregation is extended from 80% to 90%. The result comes with certain limitations like not considering benefit of plastic recycling and discrepancy due to dataset used in other geographical locations.

INTRODUCTION

The Municipal Solid Waste Management (MSWM) is one of the biggest problems facing by various countries. The proper management of solid waste is absolutely necessary given the expanding economy, rising population, and urbanization. According to the emerging idea of MSWM, turning waste into a resource through circular economy is the only practical way to fulfill the rising demand of fast urbanization. Lack of planning, poor disposal, insufficient collection, and inappropriate technology are the characteristics of MSWM in developing and underdeveloped countries, which restricted MSWM to mere collection, transportation, and disposal of solid wastes (Hemidat, et al., 2022).

The management approaches that are used internationally for MSWM differ by location, however, the common methods are landfilling, waste incineration, waste recovery and recycling. Landfilling is still the most popular method of waste management since it is the easiest and most cost-effective way to get rid of municipal solid waste (Yay, 2015). According to (Pokhrel & Viraraghavan, 2005) composting is the finest way to manage solid waste in a way that protects both public health and the environment. Other treatment options are generally more expensive than landfilling. For instance, incineration is used to get rid of 73% of the garbage produced in Singapore. By burning the garbage, the volume was reduced by around 90%. The price of incineration, however, turned out to be about six to seven times greater than the price of landfilling (Pokhrel & Viraraghavan, 2005). Among the various Municipal Solid Waste (MSW) types, management of plastic waste is a challenge since plastic consumption is growing at a pace of 4% annually, contributing to an increase in plastic trash worldwide. Globally, there are severe worries about the most efficient treatment due to the growing amount of plastic solid waste in landfills. Plastic waste can be pyrolyzed to produce bio oil and char with high calorific values that can be utilized as fuels for the plant's internal usage or as a replacement for fossil fuel in other systems (Antelava, et al., 2019).

According to (Ravichandran & Venkatesan, 2021) it is advised to create integrated solid waste management plans that are sustainable and tailored to the needs of each city or town. These plans should take into account the waste hierarchy as well as technical, environmental, economical, cultural, institutional, and political factors. One of the tools that account for the environmental factor is Life Cycle Assessment (LCA). LCA is a tool that can provide an avenue to examine the environmental impacts of the products in a cradel to grave scenario. ISO 14040:2006 and ISO 14044:2006 are the guidelines that give the principle and framework for life cycle assessment (ISO, 2006). Several studies (Yay, 2015; Gu, Guob, Zhang, Summers, & Hall, 2017; Bajracharya et al., 2022; Antelava, et al., 2019; Rigamonti et al., 2014) have used LCA as a tool for effective management of municipal waste.

However (Damgaard, 2010) emphasizes that the objective of using LCA models in solid waste management is not required to arrive at a single, definitive answer; rather, should aim to produce a recommendation of the best options when taking uncertainties into account.Additionally, and perhaps even more crucially, doing such a study using a methodical manner will aid in informing the user how to comprehend the technology or system better, enabling them to optimize their system and discover what matters and what doesn't.

So the study is aimed to apply the concept of LCA to divulge the extent of impacts in different impact categories for a MSWM practice in Kathmandu, Nepal which can be a guide for sustainable MSWM. Finding a sustainable waste treatment and disposal method involves understanding of the different emissions and resources consumption in the course of its function. Examining environmental consequences for the sustainable management of Municipal Plastic Waste (MPW) is a complementary component of using the circular economy idea to manage the plastic waste more effectively.

MATERIALS AND METHODS

Study Area and its SWM Practice

The study is carried out on Kathmandu, the capital city of Nepal. Within the Kathmandu valley, there are total 2 metropolitan cities and 16 municipalities. Kathmandu Metropolitan City (KMC) is one of them. KMC has an area of 49.45 km^2 with population of 975,453 (MoFAGA, 2022). SWM is posing a substantial challenge to the KMC and it is expected that the volume of waste will increase due to rising economy and population. Current waste management practice involves -collection (door to door, roadside pickup), sorting of waste at the transfer station and disposal to landfill site. The capacity of SWM infrastructure (pick up and transfer station) owned by KMC is not adequate so there are numbers of private players taking the responsibility of managing SWM; however the final destination (landfill site) from the both actors are the same (CBS, 2021). This study is focused only on the solid waste management by KMC. Solid waste management practice of KMC includes collection of MSW from households and other sources and taking to transfer station at Teku having capacity of 10,000 cum (CBS, 2021). From transfer station, MSW is transported to landfill site located at Banchare Dada. It is located around 25 km west of the teku transfer station. The landfill site is divided into two cells with capacity around 15,000 m^2 and 16,500 m^2. The landfills site had designed life of 25 years if MSW is unsorted.

There are two notable researches (published) on determining the composition of MSW that were undertaken in Nepal. First is based on the study conducted in 58 municipalities of Nepal (ADB, 2013) the daily waste generation is estimated to be 317gm/capita/day considering household and commercial activities. The same study also conducted on waste composition and found that the highest waste fraction as in Table 1. The high organic content indicates a need for frequent collection and removal, as well as good prospects for organic waste resource recovery. Another study (CBS, 2021) found the average waste composition as in Table 1. For the calculation, average of composition as obtained by (CBS, 2021) is adopted.

Table 1 Waste composition at different location

Composition	(ADB, 2013)	(CBS, 2021) Average of composition at Source and Transfer Station
Plastic	12.00%	14.55%
Paper	9.00%	6.99%
Organic	66.00%	63.91%
Textile	2.00%	5.53%
Metal		0.60%
Glass	3.00%	2.33%

Others	8.00%	6.10%

Goal and Scope

The first step of LCA study is to definition of goal and scope of the study. The study goal is to compare and evaluate the impact of two cases of MSW management system of KMC. Existing SWM practice and intervention in existing scenario by segregating plastic waste at source are taken as two cases for the study Figure 1. Plastic waste has proven to be both material and energy source; however, there can be impacts on environment due plastic waste. So the LCA study is aimed to see the kind of impact it will have on landfill emission magnitude due to its diversion.

Figure 1 illustrates the study's system boundary, which establishes what is and is not subject to assessment. The investigation begins with the MSW collection and concludes with landfilling. There is not a complete accounting of the waste material's manufacturing process. However, it does contain end of life in the form of landfilling. Consequently, this study is an example of gate to grave.

The functional unit is the management of per day waste generation in metric ton. MSW produced in case of KMC is 513 MT out of which only 106 MT (CPC, 2020) is handled by KMC. For the study, only waste handled by KMC is considered for the study. Further, it is important to point out that the composition of remaining MSW is almost the same as the composition of MSW considered for the study.

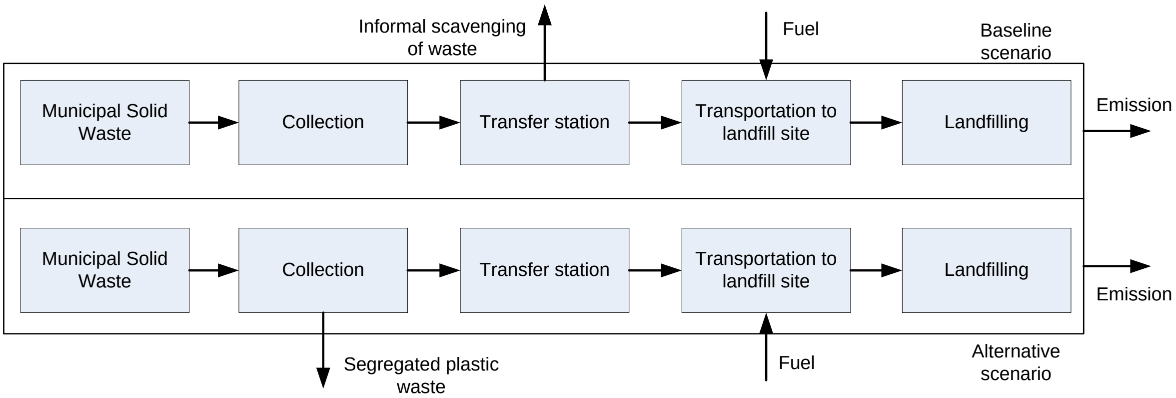

Figure 1 Typical system boundary

Scenario Development

For the study, two scenarios were developed. In the base line scenario, existing MSWM practice of KMC was considered. In this case, MSW are collected by KMC operated vehicles and sent to transfer station. At transfer station, 1 MT (CPC, 2020) of waste is separated by informal scavengers. Remaining waste is then filled to truck and sent to landfill site. In the second scenario, plastic waste segregation is introduced at the source. It is assumed that 80% plastic waste is segregated at the source which is then collected by KMC, sent to transfer station where the waste is further loaded to the truck and sent to landfill site. Both scenarios are modeled in OpenLCA1.11 platform. OpenLCA is open source free software for carrying out life cycle assessment (LCA) and is managed by GreenDelta. ReCiPe 2016 Midpoint (H) methodology is adopted to carry out the LICA and global warming, human toxicity, ozone formation and acidification potential are the impact categories selected for the study. For the sensitivity of plastic waste segregation rate on the impact categories, alternative scenario is analyzed with two cases. In the first case, plastic waste segregation is considered as 80% where as in the second case, it is considered as 90%.

Life Cycle Inventory

(a) Collection

In base line scenario, 106 MT MSW is collected per day by KMC. The waste is collected by vehicles operated by KMC. Each vehicle has their predefined route and timing. Where as in second scenario, out of 106 MT MSW, it is assumed that 80% of total plastic is segregated at the source.The volume of collected solid waste will be reduced but, it is assumed that number of vehicles used for collection that run on their predefined route and timing will be same. Vehicles will be less filled but the number of vehicle operated will be same as in baseline scenario.

(b) Transfer station operation

In the base line scenario, collected waste is delivered to transfer station at Teku. At transfer station, Informal scavengers collect about 1 MT per day of waste (CPC, 2020) and sold to recycling and reusing firms. It is assumed that waste pickers only collect plastic, paper, glass and metal waste. The composition of these waste picked by waste picker is calculated based on weightage average method. Transfer station operation includes transfer of waste received from the source to the trucks carrying waste to landfill site. In second scenario, it is assumed that there will be no scavenging of waste as in base line scenario. Transfer station operation is considered same as that in the base line scenario. Benefits of recycling of plastic waste collected by informal scavengers as in the baseline scenario are not considered and not included in the model.

(c) Transportation to landfill

In both scenarios, waste from transfer station is transported to Banchare dada landfill site located about 25 km from transfer station.Large and medium sized tipper trucksare used for transportation of MSW but only medium sized tipper truck is considered for the study. From the information collected form the site, average load carried by the medium sized tipper truck is about 5 MT. Only the emission due to diesel consumed during the transportation of waste from transfer station to landfill is considered for the study. For this purpose number of trip per day of tipper for both cases are calculated with the help of volume of waste per day and truck load per trip. Diesel consumed per day is calculated assuming the tipper run 8 km per liter of the diesel. The emission modeled with the help of ELCD database. Other possible emission source such as truck manufacturing and maintenance are not modeled.

(d) Landfilling

Landfilling process is the same in both the scenario. The only difference is the volume of waste per day and composition of waste that is being dumped in the landfill site. In the case of baseline scenario, 105 MT waste is disposed where as in the second scenario, 93.666 MT waste is disposed per day through KMC operation. The composition of waste in both scenarios is calculated shown in the Table 2. Landfilling of plastic, paper, organic waste, glass and metal are modeled as waste flow according to the ELCD database.

Table 2: Waste composition for two scenarios

Waste type	Baseline scenario (MT/day)	Second scenario (MT/day)
Plastic	14.823	3.0835
Paper	7.1236	7.4094
Organic	74.216	74.216
Textile	5.8565	5.8565
Glass	2.3694	2.4645
Metal	0.6115	0.636
Total	105	96.6659

RESULT

Table 3 summarizes information related to the magnitude of overall environmental impact due to the volume of MSW that KMC manages each day.

Table 3 LCIA result

Indicator	Baseline Scenario	80% Separation	90% Separation	Unit
Global warming	7.98700e+5	7.16992e+5	6.77129e+5	kg CO2 eq
Human carcinogenic toxicity	3.79544e+2	3.37729e+2	3.19878e+2	kg 1,4-DCB
Human non-carcinogenic toxicity	1.23320e+5	1.09853e+5	1.05776e+5	kg 1,4-DCB
Ozone formation, Human health	1.11406e+3	9.93330e+2	9.43664e+2	kg NOx eq
Ozone formation, Terrestrial ecosystems	1.13058e+3	1.00805e+3	9.57867e+2	kg NOx eq
Stratospheric ozone depletion	1.92035e-1	1.71301e-1	1.65034e-1	kg CFC11 eq
Terrestrial acidification	3.19781e+3	2.84693e+3	2.70430e+3	kg SO2 eq
Terrestrial eco toxicity	4.15508e+5	3.69761e+5	3.50302e+5	kg 1,4-DCB

The baseline scenario was found to have the greatest impact across all impact categories in comparison to the alternative scenario (80% plastic waste segregating at the source). Figure 2 displays the impact graphically as a percentage value.

Sensitivity analysis is carried out by changing plastic segregation rate at the source and examining the change in magnitude of environmental impact categories. According to the analysis, there are increased environmental benefits when segregation is extended from 80% to 90%, as shown in Table 3 and Figure 2.

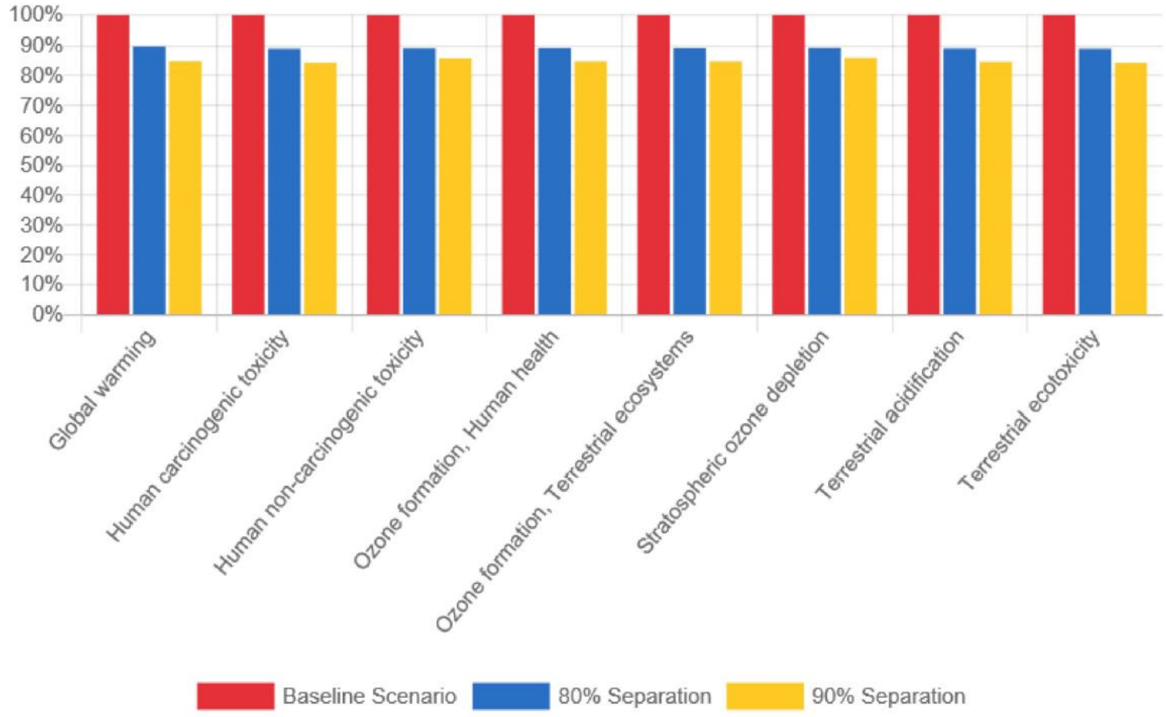

Figure 2 Relative LCIA result

CONCLUSION

In order to understand the environmental impacts, the management of the plastic waste contained in municipal solid waste handled by KMC was analyzed with the help of LCA method. In the baseline scenario, there is no consideration of sorting of plastic waste, whereas in alternative scenario, two different cases (80% and 90% segregation of plastic waste at source) were introduced to carry out the sensitivity analysis. The sensitivity analysis in the LCIA methods proves the validity of the LCIA results for global warming, human carcinogenic toxicity, human non-carcinogenic toxicity, ozone formation (human health and terrestrial ecosystem), stratospheric ozone depletion, terrestrial acidification and terrestrial ecotoxicity. According to the result, as perceived in general, higher environmental benefit was obtained with the increased segregation rate at the source when compare with the existing practice of not segregating plastic at source. Furthermore, compared to plastic garbage that is sorted at the transfer station and elsewhere, the possibility of utilizing it as a material and energy source is higher when plastic waste is separated at the source. The outcome of LCA can also be used as a reference for choosing the best alternative of MSWM

However, the study has certain imitations such as the study does not cover the benefit of recycling plastic waste. The database used for the study is ELCD and the relevancy of data is in context of European countries so the discrepancy can exist when using in the context of Nepal. The study does not categorize the segregated plastic waste into different categories such as polyethylene terephthalate (PET), polythene, low-density polyethylene (LDPE) and high-density polyethylene (HDPE).

REFERENCE

ADB. (2013). *Solid Waste Management in Nepal Current Status and Policy Recommendations.* Manila: Asian Development Bank.

Antelava, A., Damilos, S., Hafeez, S., Manos, G., Al-Salem, S. M., Sharma, B. K., et al. (2019). Plastic Solid Waste (PSW) in the Context of Life Cycle Assessment (LCA) and Sustainable Management. *Environmental Management* .

Bajracharya, S., Adhikari, A., Shrestha, P. P., & Ghimire, A. (2022). Life-cycle assessment of solid waste management in Dhulikhel Municipality, Nepal. *Journal of Environmental Engineering and Science , 17* (3), 147-154.

CBS. (2021). *Waste Management Baseline Survey of Nepal 2020.* Kathmandu: Central Bureau of Statistics, Government of Nepal.

CPC. (2020). *Baseline Study of Solid Waste Management in Kathmandu Metropolitan City.* Kathmandu: City Planning Commission.

Damgaard, A. (2010). *Implementation of life cycle assessment models in solid waste management (PhD Thesis).*

Gu, F., Guob, J., Zhang, W., Summers, P. A., & Hall, P. (2017). From waste plastics to industrial rawmaterials: A life cycle assessment of mechanical plastic recycling practice based on a real-world case study. *Science of the Total Environment* (601-602), 1192-1207.

Hemidat, S., Achouri, O., Fels, L. E., Elagroudy, S., Hafidi, M., Chaouki, B., et al. (2022). Solid Waste Management in the Context of a Circular Economy in the MENA Region. *Sustainability* .

ISO. (2006). *Environmental management — Life cycle assessment — Principles and framework.* ISO.

ISO. (2006). *Environmental management — Life cycle assessment — Requirements and guidelines.* ISO.

Rigamonti, L., Grosso, M., Møller, J., Sanchez, V. M., Magnani, S., & Christensen, T. (2014). Environmental evaluation of plastic waste management scenarios. *Resources, Conservation & Recycling* , 42-53.

MoFAGA. (2022). *Ministry of Federal Affairs & General Administration*. Retrieved Dec 25, 2022, from https://www.sthaniya.gov.np/gis/

Pokhrel, D., & Viraraghavan, T. (2005). Municipal solid waste management in Nepal: practices and challenges. *Waste Management , 25*, 555-562.

Ravichandran, C., & Venkatesan, G. (2021). 3 - Toward sustainable solid waste management – challenges and opportunities. In R. O. Rahman, & C. M. Hussain, *Handbook of Advanced Approaches Towards Pollution Prevention and Control* (p. (Abstract)). Elsevier.

Yay, A. S. (2015). Application of life cycle assessment (LCA) for municipal solid waste management: a case study of Sakarya. *Journal of Cleaner Production , 94*, 284-293.