
Yubraj Dahal¹, Bijay Thapa², Nawa Raj Khatiwada³

ABSTRACT

Municipal solid waste management (MSWM) is an engineered and environment-friendly manner which is yet to be achieved in Nepal. Increasing waste generation due to surging urbanization is threatening the environmental sanitation as well as human health. In this context, the exploration of suitable alternative waste treatment methods should be done and practiced soon. This paper was envisioned to explore the recovery potential and feasibility of composting and recycling in 8 Nepalese municipalities. The total recovery value from municipal solid waste (MSW) was NPR 43.14 Lakhs ($35,544) per day. With the amalgamation of composting and recycling, reduction of around 199,000 m³ of landfills, 4,800 m³ of leachate generation, and 81,000 (CO₂ e) of GHG emissions and saving of above 424,000 trees could be achieved per year. The analysis of the results indicates the realistic explanation of underlying reasons for integrating composting and recycling in MSWM system in all the municipalities. It is anticipated that this paper will serve as a key reference document for making decisions regarding investment in composting and recycling.

JEL Classification: Q53, Q52

Keywords: Resource Recovery, Solid Waste Management, Composting, Recycling

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1. Introduction

Landfilling is the most commonly used method of waste disposal from the past. However, the high operation and maintenance cost, the requirement of a large tract of land, fugitive emissions, and disruption from the local people are the most commonly encountered issues suggesting for its alternatives. The cost of landfilling varies between $5/ton to $25/ton and between $15/ton to $30/ton, for low-income and middle-income countries, respectively (Asian Development Bank [ADB], 2011). Research in China revealed that landfills are the largest source of Greenhouse Gas (GHG) emissions (Wang & Geng, 2015) and the emissions would decline up to 56 per cent if landfills are incorporated with combined anaerobic digestion and composting (Iqbal et al., 2019). Nowadays, the popularity of alternative waste treatment methods like composting, recycling, and incineration is also heightening given the economic and environmental benefits associated with them compared to landfilling.

In developing countries, municipal solid waste (MSW) is featured by high organic and moisture content, high density, and low caloric values ranging between 700-1,000 kilocalories on average (ADB, 2011). The same is the case with South Asia and Nepal. Landfilling is the most commonly practiced treatment option in South Asia and Nepal (ADB, 2011). On the contrary, people strongly oppose to the construction of landfill sites in their periphery on the ground of numerous issues such as not in my backyard (NIBY) behaviour, smell, litter, pollution, pets, and loss in aesthetic value (Ngoc & Schnitzer, 2009). This is also a common subject encountered by the majority of municipalities in Nepal including Kathmandu. Therefore, it is obligatory to the local bodies to necessarily find alternatives to landfills, and promote 3R (Reduce, Reuse, and Recycle) principles and source segregation in compliance with the Solid Waste Management Act 2011. Till date, composting and recycling have been limited amongst a very few municipalities (mainly Bhaktapur, Hetauda, Kathmandu, and Lalitpur). Nevertheless, the composting capacity is not satisfactory to combat the quantity of waste generation. The majority of the municipalities in Nepal possess a separate section or unit responsible for municipal solid waste management (MSWM). On average, the municipalities in Nepal spend around 10% of their annual budget for MSWM purposes, a big portion of which covers collection and transportation expenses (Asian Development Bank [ADB], 2013). The average waste disposal cost incurred in the fiscal year 2016/2017 was NPR 26,533 ($219) per day (Central Bureau of Statistics [CBS], 2019). This high disposal cost leading to poor waste management requires timely and profound research and appraisal.

The involvement of private sectors in handling and recycling MSW is accelerating in major cities of Nepal, the majority of which are Kathmandu oriented. Doko Recyclers, Blue Waste to Energy, Bio-compost Company, Nepwaste Pvt. Ltd, Clean Valley Company, and Dutch-Nepali enterprises are some frontiers tapping resources from MSW. In contradiction, alternative technology selection is a complex decision and requires multidimensional analysis. A morsel error could lead to the permanent failure of the project. For instance, a large scale MSW incineration plant in Delhi failed, which was established in 1987 with a processing capacity of 300 tons/day of worth $5.7 million, as a consequence of poor waste segregation, seasonal variations in waste composition and properties, improper technology selection, and operational and maintenance issues (ADB, 2011).

Nepal is an agrarian country with a high demand for fertilizers such as urea, Di-Ammonium Phosphate (DAP), and Muriate of Potash (MoP) and most of them are imported from abroad. In the fiscal year 2017/2018, Nepal imported 635 tons of active ingredients (a.i) of pesticides (Sharma, 2019). Moreover, the government has subsidized up to 50% for urea and other chemical fertilizers in South Asian countries (ADB, 2011). This supplements the
blooming trade deficit of Nepal. Also, the vegetables in Nepal tested higher pesticide intake (more than 90% of total intake) followed by cereals, cash crops, pulses, and fruits (Sharma, 2019; Atreya & Sitaula, 2010). Composting can be a key in screening the waste reaching the landfill sites, reducing surface and groundwater contamination, improving the recycling of materials such as paper, metal, and glass, decelerating erosion process, enhancing the efficiency of synthetic fertilizer, and shrinking the methane yield (Hoornweg et al., 1999). On the other hand, compost has been found helpful in controlling plant diseases by killing and suppressing plant pathogens (Hoitink & Fahy, 1986). Additionally, it is also a rich source of nutrients such as nitrogen, potassium, and phosphorus. Thus, for Nepal, where agriculture utilises 26 per cent of the total land and above 60 per cent of the total population are directly dependent on it, agricultural utilisation of compost can be a best option to undermine the spiking fertilizer intake in agricultural products, bridge the supply-demand gap of fertilizer, revive soil properties lost due to excessive and decades of fertilizer use, narrow down the trade deficit, and replenish the loss caused by heavy subsidy in fertilizer.

With all these issues as well as opportunities in mind, researchers examined available recovery potential from Nepalese municipalities briefly in monetary value and the corresponding environmental and economic opportunities. It is anticipated that this paper will serve as a key reference document on the decision-making process, regarding mainly initial investment, size of the plant, payback period, achievable profit, and reduction in waste management cost, to the municipalities and private sectors willing to invest in composting and recycling.

The objectives of this study are: to explore recovery potential from MSW in Nepalese municipalities, to encourage municipalities in Nepal to adopt alternative waste management options like recycling and composting, to present the fact that these options have numerous economic and environmental benefits, and to encourage private investors for solid waste management in these cities.

2. Study area and methodology

This research was completely a desk study. The method of this research looks simple but the researchers have applied systematic and scientific research design to make this study reliable and worthwhile. Moreover, the authors have designed this paper as a tool for decision-making to the municipalities and private sectors intending to invest in alternative waste treatment methods like composting and recycling.

2.1 Study area

The top eight largest municipalities of Nepal with household waste generation greater than 15 tons/day were taken into consideration. According to the ADB (2013), household waste constitutes about 50 to 70 per cent of the total MSW in Nepal. The eight municipalities are Bharatpur, Biratnagar, Birgunj, Dharan, Itahari, Kathmandu, Lalitpur, and Pokhara (Figure 1). Three out of eight, namely Bharatpur, Biratnagar, and Birgunj lie in the Terai region of Nepal, while the rest lies in the hilly region. The composition and quantity of household waste, commercial waste, and institutional waste generation in these selected municipalities as per the ADB (2013) are shown in Table 1.

2.2 Data collection

This study was primarily based on available data on MSW of Nepal to make a comprehensive study focusing on the objectives as stated in the paper. The secondary sources of data were scientific research papers, books, government and private reports, and online sources. Necessary information and methodologies relevant to this study were extracted from these sources.
Table 1

*Quantity (tons/day) and Composition (%) of Household Waste, Commercial Waste, and Institutional Waste in Different Municipalities (ADB, 2013)*

<table>
<thead>
<tr>
<th></th>
<th>TSW</th>
<th>Bharatpur</th>
<th>Biratnagar</th>
<th>Birgunj</th>
<th>Dharan</th>
<th>Itahari</th>
<th>KTM</th>
<th>Lalitpur</th>
<th>Pokhara</th>
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<tbody>
<tr>
<td>OGN</td>
<td>78.96</td>
<td>85.77</td>
<td>58.48</td>
<td>58.34</td>
<td>61.23</td>
<td>64.24</td>
<td>77.94</td>
<td>62.65</td>
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<td>PTS</td>
<td>4.63</td>
<td>5.05</td>
<td>13.7</td>
<td>15.49</td>
<td>12.56</td>
<td>15.96</td>
<td>9.81</td>
<td>8.8</td>
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<tr>
<td>P&amp;PP</td>
<td>7.84</td>
<td>5.18</td>
<td>7.44</td>
<td>11.3</td>
<td>19.35</td>
<td>8.66</td>
<td>5.23</td>
<td>11.61</td>
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<tr>
<td>HHW</td>
<td>32.52</td>
<td>29.18</td>
<td>19.08</td>
<td>25.46</td>
<td>15.07</td>
<td>233.07</td>
<td>42.15</td>
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<tr>
<td>OGN</td>
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<td>34.65</td>
<td>25.57</td>
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<td>45.44</td>
<td>39.36</td>
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<td>18.86</td>
<td>19.15</td>
<td>18.27</td>
<td>36.17</td>
<td>24.29</td>
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<tr>
<td>P&amp;PP</td>
<td>23.7</td>
<td>19.11</td>
<td>31.77</td>
<td>17.09</td>
<td>30.41</td>
<td>23.29</td>
<td>31.14</td>
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<tr>
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<td>6.82</td>
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<tr>
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<td>23.05</td>
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<tr>
<td>P&amp;PP</td>
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<td>35.49</td>
<td>50.18</td>
<td>37.81</td>
<td>40.13</td>
<td>44.28</td>
<td>41.05</td>
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<tr>
<td>IW</td>
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<td>0.27</td>
<td>0.44</td>
<td>1.28</td>
<td>29.58</td>
<td>5.35</td>
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</tbody>
</table>

TSW= Types and source of waste, HHW= Household waste (tons/day), CW= Commercial waste (tons/day), IW= Institutional waste (tons/day), OGN= Organic waste (%), PTS= Plastics (%), P&PP= Paper and paper products (%), and KTM= Kathmandu

Similarly, logical assumptions were made by the authors based on their skills and experiences in case of data unavailability and deficiency. Adhering to the fact that no detailed study on MSW generation and composition has been carried out in Nepal in recent years, this study was solely dependent on the data furnished by the ADB (2013) on MSW of Nepal.

2.3 Research method

To portray a landscape view of existing opportunities in Nepalese municipalities, the research method was designed to recognize the monetary value recoupable from household waste, commercial waste, and institutional waste separately. However, taking into account the fact that wastes like glass, metals, textiles, rubber, and leather comprise a very small fraction of the MSW, recovery potential from organic waste, plastics, and P&PP was only determined. This study applied the procedure and assumptions outlined by Ramakrishna (2016) to total the recovery value (RV) from plastics, P&PP, and organic waste. Firstly, the amount of organic, plastic, and P&PP fraction of the MSW was calculated separately for household, commercial, and institutional waste based on their composition. Secondly, the recoverable amount of compost, plastics, and P&PP was computed at the rate of 35, 50, and 50 per cent of the amount of organic, plastics, and P&PP waste, respectively.
Finally, the recovery potential from compost, plastics, and P&PP was figured out at the rate of NPR 9,600 ($79.10) per ton of compost, and NPR 24 ($0.20) and NPR 16 ($0.13) per kg of plastics and P&PP, respectively.

Furthermore, the payback period of the recommended composting plant in each municipality, excluding the investment for the land area for setting up the compost plant, was analysed using the breakeven analysis. The deployed investment cost for compost plant of different capacities was 3 tons per day (TPD) ($5,767), 6 TPD ($9,887), 12 TPD ($17,302), 25 TPD ($30,897), 50 TPD ($54,379), and 100 TPD ($93,779). Similarly, composting cost of NPR 7,646 ($63) per ton of compost including the collection cost was used (ADB, 2011). Aiming to supplement and spotlight the feasibility analysis, reduction in GHG emissions and leachate generation, reduction in landfill volume, and the number of trees that could be prevented from being cut down with the application of composting and recycling were computed. For GHG calculation, an estimate of (0.74 CO₂ e) emission per ton of MSW yearly as suggested by Barton et al. (2008) was applied, whereas leachate generation followed the formula \( V = 0.15 \times R \times A \) (\( V \) is the volume of leachate in \( m^3/\)year, \( R \) is the annual rainfall in m, and \( A \) is the surface area of the landfill in \( m^2 \)). For this calculation, an average annual rainfall of 1600 mm/year in Nepal and surface area of the reduced landfill volume with an assumed height of 10 m were considered. In the same way, the number of trees that could be prevented from being cut down was figured out with an estimate of saving of 17 trees per ton of paper waste recycling. Besides, the calculated recovery potentials were compared and analysed in terms of waste type, source of waste, and city. Results were
analysed using MS EXCEL. Imperatively, the reduction in landfill volume, GHG emissions, leachate generation, and waste volume and the salvageable number of trees were compared and interpreted to demonstrate the environmental and economic outputs of the combined alternative technology in each municipality. (Note: conversion factor, $1 = NPR 121.37)

3. Results and discussion

Figure 2 compares the RV from household waste, commercial waste, institutional waste, and the total recovery value from MSW in each municipality. The retrieval value from household waste was accounted highest in Kathmandu municipality followed by Pokhara, Lalitpur, Bharatpur, Dharan, Biratnagar, Itahari, and Birgunj municipalities, respectively. In terms of commercial waste, Kathmandu, Lalitpur, Biratnagar, Pokhara, Itahari, Dharan, Bharatpur, and Birgunj stood at 1st, 2nd, 3rd, 4th, 5th, 6th, 7th, and 8th position, respectively. Only four cities: Kathmandu, Lalitpur, Pokhara, and Biratnagar showed sizeable recovery potential from institutional waste; whilst Itahari, Bharatpur, Dharan, and Birgunj recorded minimal. City wise, the total salvage potential from MSW descends as Kathmandu, Lalitpur, Biratnagar, Pokhara, Itahari, Dharan, Bharatpur, and Birgunj.

![Figure 2. RV from household waste, commercial waste, institutional waste, and total MSW.](image)

Figure 3 illustrates the recoverable amount of compost, plastics, and P&PP with respect to the source. This study reported a considerable difference in recoverable amounts amongst household, commercial, and institutional waste. Compost outranked plastics and P&PP in household waste, whereas all of them appeared in an extensive quantity in commercial waste. On the contrary, a very low recoupable potential was calculated from institutional waste, where P&PP surpassed plastics and composting. Concerning the waste type, the recoverable mass of compost, plastics, and P&PP from MSW was 161 tons/day, 70 tons/day, and 69 tons/day, respectively. Though recoverable compost appeared in more than double proportion to each plastics and P&PP, the recovery value from plastics exceeded compost amazingly. Similarly, the recoupable mass from the household, commercial, and institutional waste was computed 156 tons, 124 tons, and 19 tons per day, respectively. Most importantly, this study revealed that Kathmandu holds the highest recovery potential from MSW, whereas Birgunj depicted the lowest. In terms of waste sources, household waste demonstrated massive potential from MSW followed by commercial waste and institutional waste. Household waste and commercial waste disclosed nearly equal potential. The figured out potential from household waste, commercial waste, and institutional waste was worth NPR 2,044,248 ($16,843), NPR 1,950,084 ($16,067), and NPR 319,592 ($2,633) per day,
respectively. The summed recovery potential from MSW in these eight cities was NPR 4,313,924 ($35,544) per day.

Figure 3. Recoverable amount of compost, plastics, and P&PP from MSW.

The waste volume to be landfilled before and after the application of the recycling facility and composting plant, along with the payback period of the recommended plant capacity, is shown in Figure 4. Composting and recycling combined waste management system gave an impression of a commendable alternative option in plummeting waste volume influx to the landfill. The whole of the available organic, plastics, and P&PP was accounted for composting and recycling. Considering the residue left from composting and recycling requires landfilling, which was 65 per cent from composting and 50 percent from recycling, the decrement in waste volume ranged between 41 per cent, in Biratnagar; to 53 per cent, in Dharan. Similarly, Birgunj experienced the second-highest reduction of 52 per cent. For Pokhara, Itahari and Kathmandu, it was 49 and 47 per cent, respectively; whilst was 46 and 43 per cent for Lalitpur and Bharatpur, respectively. The overall waste bulk plunged by 47 per cent with an average value of 47 per cent. With above 50 per cent reduction in waste volume, Dharan and Birgunj revealed unprecedented benefits of composting and recycling. In both of the cities, the reduction in waste volume over-raced the waste volume requiring landfilling after resource recovery. Moreover, the payback period of the composting plant varied from a minimum of 3 months, in Kathmandu, to a maximum of 6 months, in Dharan, Itahari, and Lalitpur. Bharatpur and Biratnagar, and Birgunj and Pokhara showed a payback period of 4 and 5 months, respectively. The largest and the smallest recommended compost plant were 100 TPD (Kathmandu), 6 TPD (Birgunj), and 6 TPD (Itahari). Dharan, Bharatpur, Biratnagar, Lalitpur, and Pokhara were suggested compost plant capacity of 9 TPD, 12 TPD, 15 TPD, 21 TPD, and 21 TPD, respectively.

Figure 5 exemplifies the environmental merits of integrating composting and recycling in the MSWM system. As per the study, the salvage number of trees was recorded far ahead in the race. Following the former, the volumetric saving of landfills stood at second, whilst GHG reduction left behind the leachate reduction and was positioned at third. In particular, the number of trees saving, landfill saving, and the reduction of GHG emissions appeared as the implicit benefits of this alternative technology option. With the amalgamation of composting and recycling, around 199,000 m³ of landfills could be saved per year, which is
slightly 44 times higher than the leachate reduction (around 4,800 m$^3$/year) and nearly 2.5 folds higher than GHG emissions (around 81,000 CO$_2$e per year). The number of trees that could be protected was above 424,000 per year. Regarding the environmental opportunities: Kathmandu unveiled the highest benefits, the lowest was in Birgunj, and the rest depicted considerable benefits. Comparatively, Pokhara and Birgunj showed equal benefits, and so on Dharan, Itahari, and Bharatpur. This study divulged a common trend in all municipalities. The four criteria, for example, the salvageable number of trees, GHG reduction, landfill saving, and leachate reduction followed the same order of benefits in each municipality.

The computed high recovery value from plastics, compost, and P&PP proves the integration of composting and recycling in the MSWM system as a suitable and promising
alternative method for a developing country like Nepal. The establishment of such facilities by both municipality and private sector can be a source of employment and income generation, directly and indirectly, to numerous people at the local level. Also, the application of these facilities could be an innovator in environmental management and protection. The narrow payback period, less than one year, with paramount recovery potential in almost all municipalities, has cemented the ground to assure and encourage municipalities and private sectors aspiring to invest in composting and recycling. Apart from this, adequate production of compost could break our reliance on other countries for chemical fertilizer, curbs depletion of soil, replenishes organic matter content of the soil, increases agricultural productivity, aids in shrinking our trade deficit, and edges the risk of developing diseases due to the consumption of extensive pesticide intake foods. Furthermore, with no doubt, the thousands of trees that could be saved from being cut down if saved and plummeting GHG emissions would bring numerous environmental benefits.

Accordingly, the nearly equal recovery value from household waste and commercial waste ascertains that huge recovery could be easily extracted from commercial waste despite its small contribution (16 per cent less than household waste) to MSW. However, to procure maximum recovery from MSW, source segregation of the waste is the only key and needs effective implementation. The retrieval value from MSW in these cities is expected to increase significantly from the calculated recovery value in this paper. This is due to the limitation that no recent data on MSW generation and composition of these municipalities is available and all the calculations are based on the data given by the ADB (2013).

4. Conclusion

The mammoth recovery potential, substantial sinking in waste volume which ultimately cuts landfill volume, and considerable reduction in GHG emissions have fully justified composting and recycling integrated waste management system as an appropriate and practicable method for Nepalese municipalities from both environment friendly and cost-effectiveness point of view. To conclude, this integrated waste management system fits best for municipalities in Nepal and South Asian countries having high organic contained MSW. Furthermore, dramatic environmental and economic advantages are the exceptional reward of this system. However, to recoup the fullest benefits of the integrated system, the authors would like to make the following recommendations to the government:

a) With no delay, detailed characterisation and quantification of MSW at the local level is the primary prerequisite of the government.

b) Encourage private investors by allowing setting up of composting and recycling amenities in government-owned land free of cost.

c) Relaxation of the taxation for the import of composting and recycling facilities.

d) Formulation of policies and programs to propel farmers for organic farming.

e) Availability of low-interest-rate loans for the investors tempted to invest in composting and recycling.

f) Establishment of joint composting and recycling facilities by the municipalities lying in close vicinity to minimize operation, maintenance as well as initial investment cost (For instance, municipality like Hetauda, Jeetpur Simara, Birgunj, Kalaiya, Kolbhi, and Nijgadh could collaborate and establish a single high capacity plant).
References


