Life Cycle Assessment (LCA) of Municipal Waste Management System of Karaj

Nematollah Khorasani, Shahram Naghibzadeh, Mohsen Ghadiryanfar and Zia Badehian

Abstract—LCA is one of the decision support systems, which can be considered for selecting the different approaches of Waste Management. In this study LCA used to investigate the Waste Management System of Karaj City. Three scenarios were defined and life cycle inventory were applied using IWM_1 model. Thereupon, the output of inventory was allocated to five impact classes included: energy using, greenhouse gases, acidic gases, photochemical smog and toxic gases. An ecological index was achieved from inventory values for each scenario. From the environmental point of view, results showed that recycling was one of the best alternatives for Waste Management. Furthermore, composting has an important role in alleviating the load of pollutants and energy usage in the Waste Management system.

Keywords—Waste Management System, LCA, Karaj.

I. INTRODUCTION

Waste is one of the inevitable productions of our society. Thus, Waste Management is a basic need of any society. Regarding the rate of waste production and its composition, different alternatives might be used for Waste Management systems. Analyzing and comparison of the environmental and technological efficiency of Waste Management systems can be performed using environmental assessment tools. LCA, the technique of investigating the environmental aspects of one production or process over the life period (from birth to burial), is one of the important decision making tools. The approach dominating this study is from cradle to grave [10]. In this concept, different stages of conducting a process or services are studied [8].

One of the applications of LCA is the comparison of the alternatives and scenarios of the Waste Management or assessment of consequences of different structures settled in the process of Municipal solid Waste Management. In Ankara, LCA was used for comparison of different Waste Management methods. In that study, five scenarios, which were applied in Waste Management, were defined and considered. Afterward, the environmental load of each scenario was inventoried and presented. Impact assessment of life cycle was not conducted and by comparison the results of life cycle inventory, suitable alternatives were chosen and presented. Finally, distance reduction from the source had the least environmental impact and was presented as the best method of solid Waste Management [7]. Comparison the different alternatives of Waste Management based on energy saving and lesser environmental impacts in Rome, showed that recycling the energy produced from Waste Management, can supply the 15% of electrical energy required in this City [12].

II. MATERIALS AND METHOD

A. Waste condition in Karaj

Based on the last statistics of Karaj Municipal, the rate of waste was 1389 ton/day at the end of 2008, 969 ton (70%) of which were corruptible materials, sludge, and gathered sediments of the city. Figure 1, shows the graph of this waste condition in Karaj.

B. Life Cycle Assessment (LCA)

The LCA of Karaj solid Waste Management system was done based on [2] in four steps (Figure 2).

C. Definition of the goals and scope

The object of this study was the life cycle assessment of the current Waste Management System in Karaj in the environmental viewpoint, and determining the priorities in decisions in order to improve the Waste Management. The borders of the studied system begin from the waste gathering from houses and ends in the landfilling or composting in factory and studied time framework is one year. Three scenarios and relevant waste management alternatives in each scenario were developed based on waste production rate (year 2008). Then alternative managements of each scenario were compared based on their environmental load. The evaluated aspects to estimate environmental loads were: water and air pollution, energy consumption and residual waste.

Scenario1. Optimizing Collection System

According to this scenario, following three alternatives were considered and compared.

A. Environmental load caused by landfilling of current produced waste. B. Environmental load due to 10% reduction of waste landfilling because of decrease in production in origin without considering the 10% reduction of distance of
transportation. C. Environmental load due to 10% reduction of waste landfilling because of decrease in production in origin by considering the 10% reduction of distance of transportation.

D. Life Cycle Inventory

Life Cycle Inventory presented in three mentioned scenarios, using the IWM_1 model [1]. This model is composed of two economical and environmental sub models [11]. In this study only the environmental sub model was used.

E. Life Cycle Impacts Assessment

In Life Cycle Impacts Assessment result of life cycle inventory, converts to the objective units and consequently managerial form would be achieved. So far has been not presented a unique methodology and standardization that having global acceptance to perform life cycle impact assessment [14]. Because at present the necessary information in order to perform life cycle impact assessment does not exist [13] and scientific methods for long time assessment, has been not presented [9]. Practically, the only approach used since the 1990s has been "lower is better". In this approach it is assumed that all values from one type of stress gathered together - without considering the place and time of stress and whether the levels of the stress more or less than the threshold value or not – and due to their inherent hazardous characteristics cause harmful changes in the environment [15]. Overall, life cycle impact assessment is done according to the standard of [5], through the four steps shown in figure 4.

F. Interpretation

Interpretation is the final stage of LCA. In this stage data is analyzed. Interpretation of the LCA includes reviewing all the
III. RESULTS AND DISCUSSION

The model of IWM was run for each mentioned scenario. In order to compare the each scenario and relevant alternatives quantitatively, inventoried values was allocated to considered impact classes. Then each impact class in inventoried values was normalized based on the rate of managed waste in each scenario and alternative. These values were multiplied by the specifying factors to calculate the considered impacts of inventoried values in each class based on the unit. In the next stage, obtained indices in each class, were multiplied by the relative weight of that class so that the indexes can be added together. So environmental load of each class based on the equivalent unit or ecological index, was calculated. Calculated values as quantitative criteria to compare environmental load of each scenario are shown in tables 1, 2 and 3 dimensionless. Each scenario acquired lower point has lesser load.

**TABLE I**
ENVIRONMENTAL LOAD OF THE SCENARIO (1) BASED ON ECOLOGICAL INDEXES

<table>
<thead>
<tr>
<th>Scenario 1-A</th>
<th>Scenario 1-B</th>
<th>Scenario 1-C</th>
</tr>
</thead>
<tbody>
<tr>
<td>19.821</td>
<td>20.020</td>
<td>19.796</td>
</tr>
</tbody>
</table>

**TABLE II**
ENVIRONMENTAL LOAD OF THE SCENARIO (2) BASED ON ECOLOGICAL INDEXES

<table>
<thead>
<tr>
<th>Scenario 2-A</th>
<th>Scenario 2-B</th>
</tr>
</thead>
<tbody>
<tr>
<td>19.821</td>
<td>19.618</td>
</tr>
</tbody>
</table>

**TABLE III**
ENVIRONMENTAL LOAD OF THE SCENARIO (3) ON THE BASIS OF ECOLOGICAL INDEXES

<table>
<thead>
<tr>
<th>Scenario 3-A</th>
<th>Scenario 3-B</th>
<th>Scenario 3-C</th>
</tr>
</thead>
<tbody>
<tr>
<td>19.821</td>
<td>17.911</td>
<td>17.666</td>
</tr>
</tbody>
</table>

Figure 5 shows that the greatest energy saving is related to the share of 10 percent recycling (scenario3-C) that in addition to energy saving, considers the waste as an invaluable source.

As it is clear in figure 6, composting emits the least amount of greenhouse gas (scenario3-B) because if the composting process is done properly, methane will not produce. Methane has potential of greenhouse effect 21 times more than CO2 [6]. Furthermore, composting leads to a reduction of input volume of waste to landfills [1]. Scenario 3-C has reduced the emission of greenhouse gases by 12% per ton of managed waste, showing the effective role of recycling in reduction of greenhouse gases.

Figure 7 shows that composting (scenario3-B), has reduced the production of acidic gases by 11% per ton of managed. This reduction is due to the reduction of H2S from anaerobic decomposition of corruptible material and reduction of used energy for the waste treatment. The highest rate of reduction of acidic gases refers to the recycling scenario (scenario3-C).
Fig. 7 Changes of impact class of acidic gases applying the management in different phases of collecting, transportation and processing

Figure 8 shows the role of transfer stations in waste management, with a slight decline in production of smog-causing factors compared with reduction the waste in origin (scenario 2-B) and has the slightly reductive trend compared with the current state. Composting shows the lowest rate of photochemical production due to the reasons described above (scenario3-B). Recycling has reduced the amount of waste transported into the landfill (scenario3-C) by (more than) 10% per ton, showing the positive role of the recycling to in reduce photochemical smog.

Fig. 8 Changes of impact classes of photochemical smog, applying management in different phases of collecting, transportation and processing

Figure 9 shows the similar trend shown in figure 4 with the difference that the negative slope of toxic outputs from scenarios 1-B, 1-C and 2-B has the slower trend so that scenario 1-C and 2-B has lesser effect compared with composting and recycling.

Fig. 9 changes of impact classes of toxic output of water and air applying management in different phases of collecting, transportation and processing

The ecological index of environmental load in each scenario and alternative considered as the outcome of all environmental actions and reactions of waste life cycle. Results of this index explain the arrangement of the environmental priorities of each phase and waste managerial processes. As it clear, in figure 10, the effect of waste management in each section of collecting, transporting and processing were as follows:

By decreasing the waste weight transmitted to the landfill with constant distance (scenario1-B) ecological indices (normal value) have been decreased due to increasing the vehicles fuel use based on each ton of waste managed. Composting has decreased the ecological index (scenario3-B) showing the effective role of composting in reduction of environmental impact. The least value of ecological index refers to the scenario of recycling processes (scenario3-C).

Fig. 10 Changes of ecological indexes applying management in different phases of collecting, transportation and processing

IV. CONCLUSION

Regarding to the results recycling is one of the best alternatives for Waste Management. Furthermore, composting has an important role in alleviating the load of pollutants and energy usage in the Waste Management system.

REFERENCES


Organization of Recycle and Transformation, Karaj, 2008.