# The Environmental and Economic Value of Waste Recycling in Makkah

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## Abstract

Every year, millions of Muslims gather in the Kingdom of Saudi Arabia (KSA) for worship, i.e. Hajj (Pilgrimage) and Umrah. The Makkah city landfills receive about 2.4 thousand tons of municipal solid waste (MSW) every day. While, these quantities become 3.1 and 4.6 thousand tons per day during the Ramadan and Hajj respectively. All of the collected MSW is disposed to landfill sites untreated, which results in greenhouse gas (GHG) emissions as well as water and soil contamination. The government considers reuse and recycling as optimum techniques for waste management following source reduction. However, the current waste recycling has been carried out mostly by informal sectors and only few recyclable materials such as paper, cardboard, metals and plastics are recycled (10-15% of total waste). The waste pickers or waste scavengers take the recyclables from the waste bins, containers and dumpsites. There is an immediate need to develop public-private partnership (PPP) to improve MSW management system in Makkah city including waste reuse and recycling. It is theoretically estimated that only by recycling glass, metals, aluminium and cardboard, climate will be saved from 5.6 thousand tons emission of methane (CH4); a major source of GHG emissions and 140.1 thousand Mt.CO2 eq. of global warming potential (GWP) with carbon credit revenue of worth 67.6 million SAR. Similarly by recycling above-mentioned recyclables, a net revenue of 113 million SAR will be added to the national economy every year only from Makkah city. Moreover, technically, the waste recycling does not require high-skill labour, complex technology and thus can be easily carried out in any urban areas like Makkah city.

Key Words: Waste recycling; Municipal solid waste (MSW); Hajj and Umrah; Makkah city; Greenhouse gas (GHG), Global warming potential (GWP)

## Introduction

Every year in Kingdom of Saudi Arabia (KSA), millions of Muslims come to perform religious rituals of Hajj (Pilgrimage) and Umrah. The central places of worship are Al-Haram that consists of Holy Mosques in Makkah and Medina and Al-Masha'ir that includes Mina, Arafat and Muzdalifah areas in Makkah (Nizami et al., 2015a). The number of pilgrims visiting KSA has been significantly increased over the past few decades due to the continuous expansion in the two Holy Mosques in Makkah and Medinah, advancement in transportation, increased security and reduced overall cost and time (El Hanandeh, 2013). The current King Abdullah expansion project of the two Holy Mosques is the largest in history, when completed, will result in an increase in the number of pilgrims to more than 5 million in a year (Arab News, 2015; Rehan et al., 2016).

In KSA, 15.3 million tons of municipal solid waste (MSW) was produced during 2014 (average 1.4 kg/capita/day) that is estimated to double to 30 million tons per year by 2033 due to the current population growth rate of 3.4% per annum (Nizami et al., 2015b, c). The Makkah city produces 2.4 thousand tons of MSW every day. While, these quantities become 3.1 and 4.6 thousand tons per day during the Ramadan (the month of fasting) and Pilgrimage time (Nizami et al., 2016). The highest waste generation occurs during 8-13 Zulhijjah (the month of Pilgrimage) and last ten days of Ramadan (Abdulaziz et al., 2007). More than 23,000 municipality workers and 450 scouts participated only in cleaning operations for the gathering of 2.1 million Muslims in 2014's Pilgrimage (Hazaimeh, 2014). Most of the collected MSW is disposed to landfills, thus resulting in air, water and soil pollution (Ouda et al., 2015; Nizami et al., 2015c).

The KSA government has adapted an integrated municipal solid waste (IMSW) approach in 2014 to optimize the economic and environmental value of waste through reuse and recycling practices (Ouda et al., 2013; Nizami et al., 2015b). The concept of waste recycling is getting significant attention nowadays, as it saves the energy that will otherwise be utilized in raw material's extraction, transportation and manufacturing, and generating huge economic benefits (Morris, 1996; Sadef et al., 2015). Therefore, recycling has become an integral part of modern sustainable waste management system (WMS) of many developed countries (Metin et al., 2003; MfE, 2007).

In KSA, waste recycling is mainly carried out at a limited scale by informal sector (Nizami et al., 2014a, b). The most recyclable materials are paper, metals, cardboard and plastics that collectively present 10-15% waste recycling of total MSW. The waste scavengers or waste pickers take these recyclable materials either directly from source or municipality placed bins/ containers or dumpsites (Abdulaziz et al., 2007). Still, many other recyclable materials such as glass, aluminum cans, steel cans and

plastic bottles that carry high economic and environmental values are not placed in the waste recycling stream. According to Arab News (2012), a loss of 75 billion SAR occurs every year to the economy of Arab countries, especially to KSA with 40 billion SAR due to the absence of recycling schemes and projects.

There is a strong need to develop public-private partnership (PPP) through formal and informal sectors to improve the waste recycling practices in KSA, particularly in Makkah and Medina. This paper aims to evaluate the economic and environmental value of waste recycling in Makkah city with ambition to solve the waste-landfilling problems and generate economic and environmental benefits to the society.

## Methodology

The economic and environmental values of waste recycling in Makkah city are calculated based on the fractions of recyclable materials such as glass, metals, aluminium and cardboard (Table 1). The energy-saving concept of Morris (1996) was used for estimating the energy savings from the recycling of these materials into same or other materials. The energy production efficiency through utilizing different resources and process technologies were also considered in the calculation of energy savings. Based on Morris (1996) findings, the energy-saving values of 5517, 64155 and 38600 MJ/ton were assumed for recycling of glass, metals and cardboard respectively. As the aluminium production process is highly energy intensive in comparison to other metal's production processes, therefore, it has been considered separately for energy saving's calculations. The recycling of aluminium into tin or other purposes contain an average energy-saving value of 336499 MJ/ton (Morris, 1996).

The overall recycling scheme of Makkah city can be more economic and environmentally beneficial if integrated in a sustainable way. In order to do that, a material recovery facility (MRF) is recommended and discussed that how it will work and will deal the recyclable materials (Figure 1). Nowadays, the aluminium is extensively used in transport industry, food and medicine, packaging, construction, electronics and electrical power transmission. Recycling of used aluminium products has been a characteristic feature of the global aluminium industry. Therefore, prospects of aluminium recycling in Makkah city is given special attention in the discussion section. Similarly, the use of polyethylene terephthalate (PET) bottles is also increasing in Makkah city. Therefore, the recycling approaches to deal PET bottles with sustainable methods are explained under the discussion section.

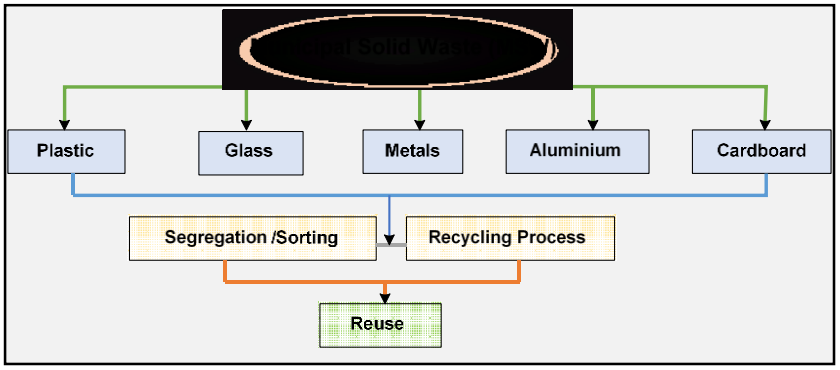


Figure 1. A recommended recycling approach for Makkah city

Table 1. Makkah waste composition* (Nizami et al., 2015a,b,c; Abdulaziz et al., 2007; Nizami et al., 2016)

| Waste type | Average waste (%)[a] | Waste quantities per year (thousand tons) |
|---|---|---|
| Food | 50.6 | 489.69 |
| Plastic | 17.40 | 168.39 |
| Paper & Cardboard | 18.6 | 180.00 |
| Textile, wood, leather | 4.06 | 39.29 |
| Glass | 2.9 | 28.07 |
| Metal | 2.71 | 26.23 |
| Others | 3.73 | 36.10 |
| Total | 100.00 | 967.76 |

*,[a], The values of waste quantities are average percentage values of different reported values. The waste composition and their quantities vary significantly at different times of the year in Makkah city; during Hajj, Ramadan, Umrah months and normal days. The values also change with locations such as Mina, Muzdalifah, Arafat, inside Holy Mosque and its surrounding areas.

## Results and Discussion

Economic and Environmental Value of Waste Recycling in Makkah

There are significant economic and environmental benefits for the Makkah city by recycling only 12.21% of Makkah MSW, including the recyclable materials such as cardboard (6.6%), glass (2.9%), metals (1.9%) and aluminium (0.81%). It is theoretically estimated that up to 140.1 thousand Mt.CO2 eq. global warming potential (GWP) will be achieved with savings of 5.6 thousand tons emission of CH4 (a major GHG). The value of revenue based on carbon credit and landfill diversion is 12.2 and 67.6 million SAR respectively. A net revenue of 113 million SAR will be added to the national economy every year only from recycling practices in Makkah city (Table 2). Technically, the waste recycling does not require high-skill labor, complex technological and can be carried out in any urban areas like Makkah city. Moreover, the typical capital and operational cost of recycling procedures is very economical with values of $0.38-$0.74 and $3.92-$5.45 respectively in comparison with other waste disposal methods (Table 2).

Table 2. Technical, environmental and economic values of waste recycling (Ouda et al., 2013; Ducharme, 2010; Ouda et al., 2015; Nizami et al., 2016)

| | |
|---|---|
| **Technical Value** | |
| Suitable Waste | Glass, Metal, Aluminium, Cardboard, Plastic |
| Technology Requirements | Low |
| Labour Skills | Low level |
| Geographical location | Urban/Industrial Area |
| **Environmental Value** | |
| $CH_4$ emission potential (tons) | 5,605 |
| GWP (Mt. $CO_2$ eq.)[a] | 140,119 |
| **Economic Value** | |
| Capital cost (ton/yr)[b] | $0.38-$0.74 |
| Operational cost (ton/yr)[b] | $3.92-$5.45 |
| Revenue from Carbon Credits ( x $10^6$ SAR)[c] | 12.2 |
| Saving from Landfill diversion ( x $10^6$ SAR) | 67.6 |
| Gross revenue ( x $10^6$ SAR)[d] | 125.1 |
| Net revenue ( x $10^6$ SAR) | 113.6 |

[a] Based on GWP of 25 for methane ($CH_4$).

[b] Recycling capital and operational cost based on plant capacity to handle 1000 t/day, considering 10 year life time of the facility and other equipments (Metin et al., 2003).

[c] At a cost of US $ 23.20/tonne of $CO_2$.

[d] The revenue from recycling materials (glass, metal, aluminium and card board) is calculated by using their resale value from MfE (MfE, 2007).

Development of Material Recovery Facility (MRF) in Makkah

For urban cities like Makkah, MRF holds great importance in managing mixed waste to maximize the recovery of recyclables (plastics, papers, glass, metals) from MSW. Moreover, the MRF helps in processing organic fraction of MSW (OFMSW) into a suitable feedstock for biological conversion processes/technologies such as anaerobic digestion (AD) and composting to generate renewable energy (biogas) and value-added product (organic fertilizer). For an effective and efficient recycling program in Makkah city, MRF should incorporate waste sorting, processing, storage, and load-out phases in their design plan. An MRF can deal with the dirty as well as clean waste. The mixed MSW of Makkah city will be treated at a dirty MRF, otherwise source-separated waste (SSW) will be sent to the clean MRF. As SSW is not practiced in any city of KSA, including the Makkah. Therefore, it is advisable to establish dirty-MRF to enhance recovery of recyclables from the urban waste stream. However, if SSW is implemented and in place in Makkah, will save more energy and economic inputs to segregate and separate the recycled materials from mixed MSW.

Recycling of Aluminium Materials in Makkah

Aluminium is one of the best metals for recycling as it does not degrade during the recycling process and requires significantly less energy to recycle than it does to make primary aluminium. In fact, recycled aluminium requires only 5% of the energy required to make primary aluminium, and has identical properties as the parent metal. The recycling of used aluminium products has been a characteristic feature of the global aluminium industry, especially in Europe and North America. They have developed robust collection systems for aluminium recycling and use in aircraft, automobiles, bicycles, boats, computers, cookware, wire and beverage cans (Zafar, 2015a).

The consumption of aluminium products is growing fast in Makkah city and is the second most widely used metal after iron. Millions of beverage cans are used by pilgrims during the Hajj and Umrah, with majority ending up in landfills. Therefore, the high market value of aluminium will provide an attractive economic incentive if recycled in Makkah city. Moreover, the aluminium will find widespread use in food packaging industry of Makkah. With millions of pilgrims visiting the Makkah city every year, it is not difficult to estimate the amount of aluminium packaging being thrown in garbage

bins. Like cans, aluminium packaging is also a good candidate for recycling. However, it needs to be separated from other packing materials before recycling. Modern waste sorting facilities are usually equipped with eddy current separators to extract aluminium fraction from rest of the packaging materials. Other technologies used for extracting aluminium from complex packaging products are repulping, mechanical separation, pyrolysis and thermal plasma process (Zafar, 2015a; Nizami et al., 2016).

Recycling of Polyethylene Terephthalate (PET) Plastic Bottles in Makkah

Disposal of PET plastic bottles has emerged as a major challenge in Makkah city, where plastics make up a major fraction of the MSW. Hundreds of thousands of plastic water and soft drinks bottles are used every year in Makkah. Recycling of PET plastic bottles, if implemented in Makkah city, will begin with collection and sorting after delivery to an MRF facility. For recycling and manufacturing the same products again, sorting and grinding are not sufficient techniques for PET bottles and containers, as they may contain contaminants/additives that require further processing. These items may include caps, labels, the plastic cups at the bottom of many carbonated beverage bottles (Zafar, 2015b).

## Conclusion and Recommendation

The KSA's aluminium and PET bottle industry can be significantly benefited from recycling initiatives in Makkah and Medina and other large urban cities such as Jeddah, Dammam and Riyadh. Both are long-term viable option for KSA, as they will reduce the need for precious raw materials and fossil fuels. Moreover, if the recyclable materials such as cardboard, glass, metals and aluminium are recycled and stopped to going into landfills, it will not only reduce the operational and environmental overburden of waste on land resources, but also generate huge economic revenue with collectively, around 113 million SAR every year. The recycling approach if implemented and practiced in Makkah city for the development of a material recovery facility (MRF), will open-up new channel of research, business and job creation for the local people.

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