

A Review of Municipal Solid Waste Management Practices in Saudi Arabia

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Abstract

Municipal Solid Wastes in Saudi Arabia are produced from different various sources related to human activities. The main objective of the management of solid waste is minimizing and eliminating risks and impacts of waste materials on humans and the environment to support economic development and superior quality of life. MSW includes household solid waste; garden (yard) and park waste and commercial/institutional waste. In Saudi Arabia, the collection of municipal solid waste from the individual or community bins then disposed of into landfill or sites dumping. Although Saudi Arabia the management system of municipal solid waste is characterized by a lack of waste treatment as sorting and recycling made increasing attention for use as income. The government in its 2017 national budget allocated a whopping amount of SR 54 billion for the general municipal services, including water drainage and waste disposal. The waste was estimated that the total amount of waste generated in 1999 was 8.5 Mt and reached about 13 Mt in 2013. The key strategy reported recycling to help conserve natural resources, reducing pollution, and landfilling. The Ministry of Economy and Planning in Saudi Arabia asserts that 35% of the total waste produced in the country is recycled.

Keywords: Municipal Solid Waste; Solid Waste Management; Household; Waste Handling; Damman City

Introduction

Municipal solid waste is defined as the waste collected by municipalities or other authorities. Municipal solid waste usually includes household solid waste; garden (yards), park waste, and commercial/institutional waste [1]. Solid waste generation in the Kingdom of Saudi Arabia is concentrated in the largest cities such as Riyadh, Jeddah, and Dammam - that exceed 6 million tons annually, which gives an indication of the magnitude of the problem faced by civil agencies. More than 75 percent of the population is concentrated in urban areas which makes it imperative for the government to initiate measures to improve the recycling and waste management scenario in the country [1,2].

Municipal solid waste is often generated from several sources as there are variable human activities. Several studies indicate that much of the municipal solid waste from developing countries is produced from (55-80%), followed by commercial or market areas (10-30%) with varying amounts of streets, industries, institutions, etc [3-5]

The Management of Municipal solid waste is a main service in the community that can be used to refer to the collection and treatment of solid waste. It better addresses a range of public health, conservation, economic, aesthetic, engineering, and other environmental considerations. It also provides solutions for recycling items that do not belong to garbage or garbage so that SWM is about how to change the waste case to be used as a valuable resource. It must be embraced by every family including business owners worldwide. Manufacturing has brought in a lot of good and bad things, too. One of the negative effects of industrialization is the production of solid waste, as solid waste is produced from different activities such as industry, residence, and commercial activities in a specific field and also, it can be treated in different ways. In this way, Landfills are usually classified as municipal, construction, sanitation industrial waste sites. Also, it can be classified on materials, such as paper, glass, metal, plastic, and organic waste. Classification may also depend on possible hazards, including infectious, flammable, radioactive, and toxic or non-toxic waste. This category is also related to the origin of the waste, such as household, commercial, industrial, institutional, construction or machinery [1].

The main objective of the management of municipal solid waste is to minimize and eliminate the adverse impacts of waste on human health and the environment for supporting economically developing and superior quality of life. This is to be done in the most efficient manner possible, to keep costs low and prevent waste buildup [6,7].

There are some functional components of the municipal solid waste management such as waste generation this contains any activities involved the identification of any materials that are no longer usable and are either gathered for systematic disposal or thrown away [8], onsite handling, storage, and processing this related to different activities of generation of municipal solid waste, which to facilitate the process of waste collection, for example, waste containers are placed at sites that generate sufficient waste, and waste collection which is a critical stage of municipal solid waste management and this includes activities such as collecting of municipal solid waste from different bins or containers, and collecting of municipal solid waste at the site where the collected vehicles are emptied, waste transfer and transport these are the activities involved in transport the waste from the local sites waste collection locations to the regional waste disposal site in large waste transport vehicles, waste processing and recovery this refers to facilitate equipment and technique which employed to recover reusable or recyclable materials from the waste stream and to improve the effectiveness of other functional elements of waste management so that, the segregation at source of waste is one of the traditional fractionation methods and fundamental steps in an integrated waste management system with the potential to provide data on waste generation and the quality of the fractions. However, the success of any designed waste segregation system will depend largely on the active participation of the waste generators in the various communities and how they comply with the principles of sorting and separation of the waste [9,10] and final disposal: The final stage of waste management. It involves the disposal of municipal solid waste and materials in locations such as landfills or waste-to-energy facilities. The presence of public-private partnerships (PPP) improves solid waste service as good duty at less cost [11-13].

Most of the municipal solid waste is removed from houses through community garbage collection and then transported to landfills. Garbage is buried in landfills, but it still produces unpleasant odors. In addition, rainwater can seep through landfill sites and seep out of pollutants from the landfill. Then it is transported to nearby water bodies. Pollutants can also contaminate groundwater, which in turn leads to contamination of drinking water [14,15].

The financial monitoring and evaluation aim in recovering by payment of money to cover the operational expenditures of the service to remain the investments of management in large. These methods are seldom used and the municipality rarely knows the actual cost of providing solid waste management [16-19].

Municipal Solid Waste Management in Saudi Arabia:

Saudi Arabia has been facing rapid population growth, urbanization, and industrialization, which's also lead to a high generation of solid waste. The country's population was estimated at 16.1 million in 1992, which is increased to 27.1 in 2010 [20]. According to global Media Insight the population of Saudi Arabia per years in Figure 1.



Figure 1: The population rating by year in Saudi Arabia

In Saudi Arabia, municipal solid waste is collected from individual or community containers and disposed of in landfills or landfills. The management system of waste in Saudi Arabia is characterized by the absence of waste disposal fees and tips. Recycling, reuse, and energy recovery are still at an early stage, although they are receiving increasing attention. An active informal sector is sorting and recycling waste. The recycling rate ranges between 10-15%, mainly due to the presence of the informal sector that extracts paper, metals, and plastics from municipal waste. Most recycling activities are manual and labor-intensive. Composting is also gaining increased interest in Saudi Arabia due to the high organic content of local solid waste (around 40%). Efforts are also underway to spread waste-to-energy technologies in the Kingdom. All activities related to waste management are coordinated and funded by the government [21,22].

The Saudi government realizes and aware of the urgent demand and needs for waste management solutions, and is investing heavily in solving this problem. The National Budget for the year 2011 allocated 29 billion Saudi riyals to the municipal services sector,

which includes water drainage and waste disposal. The Saudi government is making concerted efforts to improve recycling and waste disposal activities. The Saudi visa for qualified waste management professionals will go a long way in improving the country's waste management situation.

The government of Saudi Arabia is conscious of providing a lasting solution for solid waste management issues in the country by investing heavily in the sector. To achieve its target, the government in its 2017 national budget allocated a whopping amount of SR 54 billion for the general municipal services, including water drainage and waste disposal [23-25]. In Dammam City, the government has been budget for solid waste management in the last five years which is shown in Table 1.

No	Budget of Solid Waste Management (2017-2018)	Budget (SR)	
		First Location Area (East & Middle of Dammam)	Second location Area (West of Dammam)
1	Contracting of first Location Area	19764004160	316014911
2	Contracting of first Location Area	158007456	9882002080
Total		474022367	29646006240

Table 1: Budget of municipal solid waste management in riyals (in five years)

Municipal Solid Waste generation:

Most of the municipal solid waste is produced in some of the eight main cities of KSA (Table 1). The rate of sustainable waste generation in KSA is 15.3 Mt/y with an average rate of 1.4kg/capita/d [26,27]. The environmental Affair and Ministry added regulations for management and handling of sustainable waste from collection in the source to final disposal of landfilling with a program of energy recovery but this will be activated later but the waste is dumping into landfill without recycling or combustion [28,29]. The dumping sites in KSA are expected to reach their capacities in the coming few years [30]. Thus, it should be a shift from prevailing waste management to advanced technologies such as energy recovery.

The waste produced in the Kingdom of Saudi Arabia contains a large amount of organic waste (about 40%). Organic waste consists of food waste from different various sources such as hotels, restaurants, canteens, homes, etc. [31]. In order to convert this organic waste into a valuable product, composting is an economical and environmentally friendly method [32].

In Saudi Arabia, it was estimated that the total amount of waste generated in 1999 was 8.5 Mt. This figure has been increasing dramatically 10.4 Mt in 2004 [33] and reached about 13 Mt in 2013 [34]. The Figure is predicted to reach about 18.4 Mt in 2025 [35]. Additionally, the average per person waste generation rate as in the year 2004 was 1.2 kg per day (kg.d-1), however, this amount reached about 1.5 kg.d-1 in Riyadh, and 2kg.d-1 during peak months in Makkah city as reported by MEP, (2005) [16]. In 2013, however, MOMRA reported that the average percentage for all citizens in the Kingdom of Saudi Arabia was 1.3 kg per person per day (kg. p-1. d-1). This figure differs between 1.5 kg. p-1. d-1 in majorities (Riyadh, Makkah, Medina, Jeddah, Dammam, and Al-Ahsa), 1.2 kg. p-1. d-1 in medium cities, and 0.8 kg. p-1. d-1 in small cities and villages [36].

Region /City	Population (millions)	Amount of waste (x 103tonsper year)
Riyadh	5.328	2,871
Jeddah	3.456	1,888
Makkah	1.675	915
Madinah	1.18	645
Al-Taif	0.987	540
Dammam	0.803	1093
Al-Hassa	0.6	681

Table 2: Solid Waste production in different cities of KSA (Ouda, et al., 2013)

In municipal solid waste, plastic is the second most-produced waste in Saudi Arabia. Only 15-20% of all plastic waste produced is recycled by the sorting method while disposing of plastic waste in a landfill creates an environmental and operational heavy burden for a landfill due to the slow decomposition process. In this context, the pyrolysis process can be used to treat plastic waste. With power generation in the form of fuel oil and valuable products like coal [37,38].

Municipal Solid Waste Collection and Storage

In Saudi Arabia, solid wastes are collected from households or community bins which are disposed of in safe landfilling or dumpsites. The management system of municipal solid waste is characterized by a lack of waste disposal facilities and the absence of tipping fees. Although they are getting increased attention, solid waste sorting, recycling, reuse, and energy recovery are still at an early stage, currently, the informal sector is the major driven force to waste sorting and recycling. It was reported that the rate of recycling in Saudi ranges from 10-15%, which is mainly influenced by the presence of the informal sector which extracts paper, metals, and plastics from municipal waste. [23] However, there is low participation of residents in the formal waste separation and recycling. The degree

or level of residents' waste sorting and recycling practice has not been investigated and understood in Dammam city. Moreover, it is unclear if residents' sustainable waste handling practice (sorting and recycling) can be predicted by socio-psychological and external variables, as they have been found to have predicted waste management behavior in various countries [39,40]. For the purpose of this study the following variables will be focused on; attitude, awareness, perceived behavioral control, willingness (internal /psychological factors), social influence, market incentives and government facilitators (external factors), income level, and gender [demographic (moderating) variables [41].

In related to data from Eastern Province Municipality of Dammam City, Dammam is one of the largest Saudi Arabia cities in terms of area and the production of municipal solid waste the quantities of solid waste generated range from 20,000 to 35,000 m³ per month, including East, Central and West Dammam in their markets and all the waste is collected daily only once a day minimum. They use one-wheeled vehicles and two-wheelers for the first transport of solid waste to the storage area.

Municipal Solid Waste Transportation and Treatment

The equipment types which are used in the sanitary landfill are Bullets, bulldozers, bulldozers, and 16-square-meter dumpers. Solid waste is collected from the different areas of the Dammam neighborhoods to the assembly areas with containers of 15 m³ and the waste is transferred temporary station which is provided through the Eastern Region Secretariat in the first area (East and Central Dammam) and the second area (west of Dammam), where the Secretariat provides about 40 vehicles for the removal of solid waste from neighborhoods and main streets every three months. Also, they use trucks with a cover that opens automatically. There are 115 vehicles or trucks, and the transport of other wastes, such as furniture, appliances, etc., are transported through small trucks and are open and have a capacity of approximately 15-20 m³ there are two types of vehicles. The first type is the skis 7-yard which is about 32 m³ and the other type is Dint 2.5 yards then the solid waste is transported only one time per day at minimum to the final disposal without any treatment into the sanitary landfill and that is done through contracting with private companies to transfer solid waste from the final collection sites to the sanitary landfill in Baqeeq also, the type of containers is from iron steel and its capacity is 15 m³. All the solid waste is buried in a sanitary landfill (100%). The cleaning contractor transfers municipal solid waste to the sanitary landfill under the supervision of the regional secretariat and they transport the waste to the final burial place where burial is done

Sanitary landfilling in Saudi Arabia

Landfilling is the last stage of the waste disposal method that has different liners with a cover of the earth. It is the most used method and more economically in most developing nations. A landfill is a waste management facility designed for the disposal of solid waste. The most essential components in landfills include the bottom liners and top covers that help to prevent the penetration of leachate into the soil. It also generates landfill gases such as CH₄ which is capable of causing pollution and leachate that can harm man and natural systems. Landfill gases are produced when methanogens decompose complex molecules, are primarily methane and carbon dioxide (up to 90%), but also include CO, N₂, alcohols, hydrocarbons, organo-sulfur compounds, and heavy metals. [42] Leachate is capable of polluting surface water and groundwater. These cases can be treated and further be used for energy generation. Additionally, the bioreactor landfill is among the evolving technologies that should be introduced in the major cities of Saudi Arabia because of its importance in utilizing the Landfill gasses for electricity generation. This emerging technology is important in saving the global warming issues of the world and minimizing the electricity consumption of waste disposal plants [43].

The description of the Sanitary Land filling is about 3 million square meters at the start of its operation. The landfill shall be filled in about 5 years according to the available and planned area and the solid waste is transported into the landfill approximately 6000tons per day, Table 2 the description of a landfill in Baqeeq which is far away from Dammam 40km.

No	Sanitary Landfill	
1	Total Area (m ²)	3,000,000
2	Landfill capacity (tonnage capacity / ton)	176218
3	Estimate remaining (annual)	3
4	Quantity of waste deposited per day (ton / day)	6000
5	Distance from nearest collection area to site (km)	45
6	Method of disposal of waste before landfill (treatment)	No found

Table 3: The description of landfill in Baqeeq

Waste Recycling in Saudi Arabia

Solid waste recycling refers to processing used materials (waste) into new useful products in order to reduce the use of raw materials that would have been used. Recycling has been reported as a major strategy with which to achieve sustainable solid waste management due to its environmental and economic benefits. It helps to conserve natural resources, reduce pollution and landfill, save energy, as well as improve the quality of the environment and public health [25].

Although the Ministry of Economy and Planning in Saudi Arabia asserts that 35% of the total waste produced in the country is recycled [22] the environmental report of the Cooperation Council for the Arab States of the Gulf stated that the present rate of

recycling in KSA is only 23.5% of the total waste [19]. This recycling method majorly happens in the main Saudi cities including Riyadh (capital city), Jeddah (second biggest city) and Dammam. [26] Some of this recycling takes place in Saudi Arabian factories whereas the remaining is exported to other countries like India and China. This is because the recycling facilities often are meant for recycling industrial waste as it is cheaper and cleaner than sorted municipal solid waste [15].

The concept of waste recycling has given increasing attention in the Kingdom of Saudi Arabia in recent years. The country produces around 15 million tons of municipal solid waste every year at a daily rate of 1.4 kg per person. This rate is expected to double (30 million tons per year) by 2033 with the current annual population growth rate of 3.4%. The main components of municipal solid waste in Saudi Arabia are food waste (40-51%), paper (12-28%), cardboard (7%), plastic (5-17%), glass (3-5%), wood. (2-8%), Textile (2-6%), minerals (2-8%) ... etc depending on the urban activity and population density of the studied area [23].

In Saudi Arabia, recycling is still in its infancy, and metal and cardboard recycling is the main recycling practice, which covers 10-15% of the total waste and is usually undertaken by the informal sector. Waste pickers or waste collectors take recyclables from waste bins and containers around cities. The waste recycling rate often becomes high (up to 30% of total waste) in some areas of the same cities. Recycling is also taking place at some landfill sites, which cover up to 40% of total waste by involving formal and informal sectors. Recycled products are glass bottles, aluminum cans, steel cans, plastic bottles, paper and cartons, waste tires, etc. depending on the region, facilities available and parties involved [33].

Empowering the Community Through Environmental Education in Waste Management Practices

Environmental education is a primary way by the government to educate all citizens in the Kingdom of Saudi Arabia towards waste reduction and utilization as a resource. In this regard, primary and secondary education in schools and colleges can have a significant impact on sustainable waste management practices in Saudi Arabia. In addition, environmental education not only describes the environmental issues of solid waste but also gives a roadmap for agricultural engineering in Saudi Arabia to move forward towards sustainability where the treated household waste (compost) can be a good adaptation of soil and nutrients in agriculture. Moreover, a huge amount of waste generated from agricultural fields can be used to convert waste to a power plant in Saudi Arabia. Hence, educating individuals about the environment may also open a business opportunity in Saudi Arabia.

Several attempts were made to encourage residents' participation in solid waste sorting and recycling activities in different countries. One of the strategies was through giving incentives (e.g., monetary reward), especially on consumer recycling. However [44] posited that economic incentives can only be used to achieve short-term recycling participation. Internal incentives, such as socio-psychological factors, should also be considered as an effective means to increase

long-term participation in waste sorting and recycling. Additionally, the provision of recycling facilities and programs that are targeted at creating people's awareness and enhance their actions will greatly determine the success of waste separation and recycling goals(45),(46). Positive changes in people's attitude and behaviors depends on understanding differences in the socio-psychological background of the individual, which influence their decision on whether or not to participate in waste sorting and recycling activities. People that are willing to reduce the environmental impacts of the waste they produced, through what they buy and how they deal with waste in their homes and believed waste sorting and recycling would have a major impact on improving the environment, can only do that if there are facilitating conditions and proper policies that guide their actions and participation [47]. Therefore, a greater effort is required to motivate and enlighten people to understand and appreciate the importance of responsible and sustainable waste management practice and to manage their waste in a more sustainable manner by sorting waste at source and recycling it.

Conclusion

This review article highlights the municipal solid waste management practices in Saudi Arabia which provide different scenarios such as waste generation, collection, and disposal. It also highlights the importance of different MSWM systems such as recycling, composting, anaerobic digestion, environmental education, and landfilling. The significance of these methods did not only stop at minimizing environmental problems, but they also have the potentials to maximize the economic and technical aspects of waste. It is believed that sorting of waste, as well as electricity and biogas recovery, would be the best option for MSWM in Saudi Arabia. Where integrated solid waste management should requirement in municipal solid waste management to achieve the aim of solid waste management practices and attain the environmental goals in reducing the associated waste impacts. Furthermore, Waste to Energy practices prevents the loss of the potential material from municipal solid waste that increases the environmental and economic impacts. Nevertheless, giving incentives and training to the formal and informal sectors will help significantly to separate waste at the source that reduces the losses of energy and material.

To enhance our theoretical and practical knowledge of the behavioral changes that lead to households' participation in recycling, this study adopts the theory of planned behavior as the theoretical foundation of this research, which has been widely applied in various pro-environmental behavior studies. Due to the inadequacy of the theory in providing a comprehensive explanation of factors influencing residents' participation in waste sorting and recycling, the present study tends to introduce and incorporate some external variables as possible contributing factors. The additional variables hypothesized to be influential in determining residents' willingness to participate in solid waste handling practice include social influence, market incentives, and government facilitators. Additionally,

the management of solid waste is considered a good investment because it is supporting incorporated some demographic variables to investigate their moderating impact on residents' willingness to participate in sustainable waste handling practice.

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