Municipal Solid Waste Management Practices and Opportunities in Saudi Arabia

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Abstract—**Municipal solid waste management has been given serious attention by the authorities of Saudi Arabia (SA). This study focuses on municipal solid waste (MSW) that predominantly contains food, paper, and plastic waste. However, improper handling of MSW causes several environmental and human health issues. Therefore, it is necessary to review the current practices and future opportunities that have been adopted for solid waste collection, handling, and disposal. Considering the current scenario, this study proposed a reversal approach for MSW management. This study considered that MSW generated in SA has great potential to be converted into wealth. Hence, considering the hostile environment anaerobic treatment and incineration for MSW has been proposed in this study for future research.**

Keywords-municipal solid waste; disposal practices; environmental issues

I. INTRODUCTION

Generation of municipal solid waste (MSW) is a common issue and its production is being increased gradually as the commercial and industrial activities extend [1]. Currently, MSW in Saudi Arabia (SA) is considered as a significant issue, the annual generation of MSW in SA is 14×10^6 tons [2], whereas most of MSW is generated in the main cities: Damman, Hofuf and Riyadh in the West and Jeddah, Medina and Mecca in the East. The annual production of MSW from only three of the main cities, namely Jeddah, Damman and Riyadh is more than 6×10^6 tons [3]. This huge generation of MSW creates serious environmental and public health issues. Improver MSW management affects all stakeholders and particularly the public. However, improper dumping of urban waste could affect the landscape and pose environmental and public health threats. Particularly, domestic waste, which is organic in nature, poses a serious threat, since it creates conditions favorable to the survival and growth of microbial pathogens [4]. Therefore, many studies have been conducted to overcome the solid waste (SW) issue, particularly the issue of managing MSW. Details of previous studies and their key findings are reported in Table I. It was observed in earlier studies that there is a growing concern about the MSW management in each part of the country. However, most studies highlighted that the MSW of SA have great potential to generate electricity. It was stated that burning of SW can achieve high power generation [5]. MSW generated in SA is mostly comprised of organic waste, which can be utilized to produce biogas for energy production [6]. It is important to promote waste to wealth strategies and research for possible opportunities for the future [7].

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TABLE I. PREVIOUS FINGINGS

Ref.	Objectives	Key findings
[3]	MSW disposal optimization.	Combustion of MSW can reduce the load of landfill and procure electricity preferable with eco-friendly combustion technology.
[5]	Energy recovery from waste.	Incineration of SW can achieve high power generation.
[6]	Energy recovery from waste.	Biogas can be produced through organic waste.
[8]	Household waste management.	Quantity and quality of waste can be minimized by increasing awareness through education and media.
[9]	Energy recovery from waste	Annually 1.03 and 1.55TWh of electricity can be produced from waste.
[10]	MSW practices.	Need to enhance awareness about waste sorting at source, separate bins to be introduced, and strong rules need to be implemented.
[11]	Recycled plastic waste (RPW) to modified asphalt binder.	RPW cannot meet the requirements of elastic recovery for polymer-modified asphalt.
[12]	Renewable energy resource (RER).	MSW has great potential as RER.
[13]	MSW management.	MSW in SA contains about 40% organic materials. Therefore, it has great potential to produce energy through anaerobic digestion.

Previous studies [5, 6, 9, 12] indicated that MSW is currently considered as a good source for energy production. However, the method of its handling is debatable. Therefore, this study aims to identify the current practices and opportunities for the handling of MSW around the globe and in SA. This study summarizes important information regarding MSW management in SA and proposes potential opportunities considering environmental preservation and sustainable development.

II. THEORETICAL APPROACH TO MINIMIZE WASTE

The current practices of MSW handling in SA are presented in Figure 1, which indicates that most of MSW goes directly to landfills, and less consideration has been given on recycling, composting or source reduction. However, this approach creates environmental issues in terms of leachate generation from landfills and contaminated soil and underground water. The current practices are not environmentally acceptable but are intensively adopted due to the unavailability of advanced technologies and skilled professionals. The switching from one method to a more advanced one is very hard for the authorities [15], therefore this paper proposes the reversal approach as shown in Figure 2, which demonstrates that first priority should be given to the source reduction or source minimization in order to produce less MSW [16]. This requires continuous emphasis on the importance of waste minimization practices through education and electronic media and the promotion of the 3R (Reduce, Recycle and Reuse) approach. However, 3R approach can also be applied at the source of waste generation. The government should make strong rules and increase awareness to alarm the public. Successful MSW management can be achieved by adopting reversal approaches as proposed in this study.

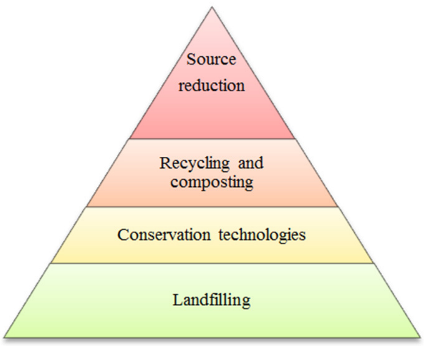

Fig. 1. Current practice.

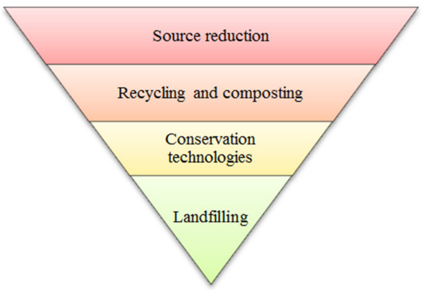

Fig. 2. Reversal approach.

III. ENVIRONMENTAL ISSUES

MSW has been considered as a valuable source for recycled materials and energy [17]. It could give numerous benefits in countries like SA. Environmental issues associated to the MSW handling in SA and other countries have been given serious attention [5]. The method of handling MSW is challenging for the authorities [12]. It was previously well recognized that there are three methods, which are commonly in practice at SA as shown in Figure 3: landfilling, anaerobic digestion and combustion/incineration. However, every method has some consequences on the environment.

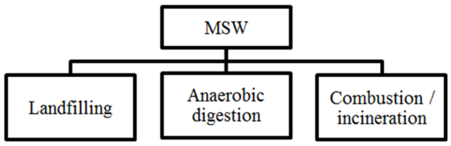

Fig. 3. Methods of handling MSW

A. *Landfilling*

Landfilling is the most common method for the disposal of MSW [18]. However, it occupies huge areas and creates environmental problems in terms of leachate and undesirable gas production. The leachate produced by the landfills can contaminate the soil and underground water. Besides that, landfills also affect their surrounding environment, habitats, cultivation lands, commerce and recreational areas [2].

B. *Anaerobic Digestion*

It was noticed that MSW generated in SA mostly contains organic waste, which indicated its potentiality to produce energy through anaerobic digestion [19]. This method produces methane (CH_4) gas [20], which could be used to produce electricity, but this process leaves a by-product known as sludge, which requires huge areas for drying.

C. *Combustion/Incineration*

The best practice is the combustion of MSW to generate electricity. This is globally the most acceptable and widely used method. However, this process leaves a by-product known as MSW ash. This ash can be used as cementitious material contributing to sustainable concrete production [21]. Currently researchers are emphasizing on the utilization of MSW to develop waste to energy practices with minimal environmental impact [22-24].

IV. MSW ASH UTILIZATION IN CONCRETE

MSW has been considered as hazardous and there is a dire need to reduce its volume [25]. Incineration is a useful technique to reduce the quantity of waste up to 70% by weight and 90% by volume [26]. The incineration process of MSW generates electricity but leaves a huge volume of ash known as MSW ash. This ash is generally disposed in landfills, creating environmental problems and increasing landfill cost. Researchers are looking for ways to manage this ash as alternatives to open dumping and landfills [21, 26]. Based on its chemical properties, it was declared that MSW ash has a good potential to be utilized as cementitious material in concrete production [27, 28]. MSW ash is obtained from different locations, its chemical composition is evaluated and the possibility of posing pozzolanic characteristics comparable to class-C as per ASTM C618 [29] is identified. Si, Al and Fe are the key indicators that represent the pozzolanic activity of ashes. If the combined sum of SiO_3, Al_2O_3, and Fe_2O_3 is greater than 50%, MSW ash can be utilized in concrete to enhance its strength and durability [26, 27]. The properties of MSW ash indicate that it also contains high amounts of CaO, which could be beneficial in the hydration process of the cement paste in concrete [30]. Besides that, it contains around 5.27% SO_3 which is allowable for pozzolanic ashes. Ash blending can provide a positive pozzolanic reaction. The chemical composition of the MSW ash could vary according to its type [27], but in almost all cases it contains high amounts of silica dioxide. The comparison of the chemical properties of MSW ash with ordinary Portland cement (OPC) as provided by [31] is shown in Table II.

TABLE II. CHEMICAL PROPERTIES OF MSW

Sample	**MSW Ash [27]**	**OPC [31]**
Chemical Content	%	%
Silica dioxide (SiO_2)	53.16	20.61
Aluminium trioxide (Al_2O_3)	3.98	3.95
Ferric oxide (Fe_2O_3)	1.40	3.46
Calcium oxide (CaO)	19.13	63.95
Titanium dioxide (TiO_2)	0.18	0.20
Potassium oxide (K_2O)	0.94	-
Magnesium oxide (MgO)	1.49	1.93
Phosphorus pentoxide (P_2O_5)	5.00	-
Sulfur trioxide (SO_3)	5.27	3.62
Zirconium dioxide (ZrO_2)	0.67	-
Sodium superoxide (NaO_2)	6.67	-

V. CONCLUSION AND RECOMMENDATIONS

The main conclusions and recommendations regarding future research are:

- MSW generated in SA contains about 40% organic waste, which indicates its potentiality to produce energy through anaerobic digestion.
- The abundant production of MSW increases the demand for landfills, which occupy huge areas of land and create environmental problems.
- Considering the energy production through MSW, incineration is the best solution, which can reduce the waste 70% by weight and 90% by volume. The by-product of incineration process known as MSW ash can be utilized in concrete production.
- MSW ash is characterized as pozzolanic material, which could deliver positive influence on the properties of concrete.

Hence, a reversal approach has been proposed for the minimization of MSW at the source. This approach could reduce the cost of segregation and transport. Besides that, this study suggests the incineration process for safe handling of MSW. However, the ashes produced through this process, can further be utilized in the production of sustainable and durable concrete.

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