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An Integrated Solid Waste Management System in Kuwait

Abdalrahman Alsulaili[+], Bazza AlSager, Hessa Albanwan, Aisha Almeer and Latifa AlEssa

Civil Engineering Department, Kuwait University, Kuwait

Abstract. Waste generation is increasing dramatically in Kuwait. The increase in waste generation adversely affects the environmental, financial, and social situation. Most of the waste in Kuwait is dumped in insanitary landfills in an uncontrolled manner. Landfills occupy extensive land area. In small countries such as Kuwait, the scarcity of land is a challenge and is the main motivation for this study. To overcome the waste problem, an Integrated Solid Waste Management System (ISWMS) was adopted to apply the "4 Rs" strategy, in conjunction with a sanitary landfill. The strategy is a systematic solution to minimize and benefit from waste material. The first two R's are Reduce and Reuse, which can be accomplished through an awareness campaign. The remaining two R's are Recycle and Recover, which formed the core of the study and were accomplished by designing seven recycling and recovery plants that separately deal with the following waste materials: plastic, tires, paper, metal, glass, and organic and construction and demolition (C&D) waste materials; these plants are in addition to a sorting plant for the primary sorting of mixed materials. The demand resulting from the quantities of waste that will be generated in the next 25 years is estimated by a forecast used to design the recycling and recovery plants. The last and least preferable option for dealing with waste is landfilling. A sanitary landfill was designed based on international scientific standards. Findings derived from this study showed that 76% of Kuwait's waste are recyclable. The raw materials produced by the recycling plants will be sold to gain a revenue of $ 134 million USD annually, whereas the non-recyclable materials will be sent to a sanitary landfill.

Keywords: 4Rs, waste management, reduce, reuse, recycle, recover, landfill.

1. Introduction

1.1. Types of Waste

Most people think that waste is worthless material to be thrown away and that it cannot be reused for useful purposes. This indicates the inattention of people to waste as a great resource. In fact, waste are leftovers that can be valuable once separated into recyclables and non-recyclables.

On the basis of their physical state, waste are classified into solids, liquids and gases. This study mainly discusses solid waste, which is classified according to its resource and material types. Sources of solid waste include household, industrial, construction and demolition, commercial and agriculture waste. Material types discussed in this study include plastic, tires, paper, metal, glass, organic and construction and demolition (C&D) waste.

1.2. Current Situation

1.2.1. Statistics

According to the Kuwait Central Statistical Bureau [1], quantities of waste are increasing annually, as shown in table 1. The percentages of different types of waste in the MSW stream in Kuwait are represented in Fig. 1, based on data from the Industrial Bank of Kuwait [2]. As shown in Fig. 1, organic waste constitutes the largest proportion of waste, making up 50%, whereas paper and plastic come in second and third positions with 21% and 13%, respectively.

[+] Corresponding author. Tel.: + 965 24983733; fax: +965 24817524
E-mail address: a.alsulaili@ku.edu.kw.

Table 1: Waste Quantities in Kuwait [1]

Year	Domestic Solid Waste (tons)	Construction Waste (tons)
2002	1,059,880	4,792,780
2003	976,185	3,797,770
2004	840,005	4,309,200
2005	836,610	4,718,370
2006	987,295	4,187,909
2007	1,000,565	3,926,280
2008	1,310,036	4,421,565
2009	1,153,233	3,606,804
2010	1,408,433	4,165,855
2011	1,350,645	6,897,786

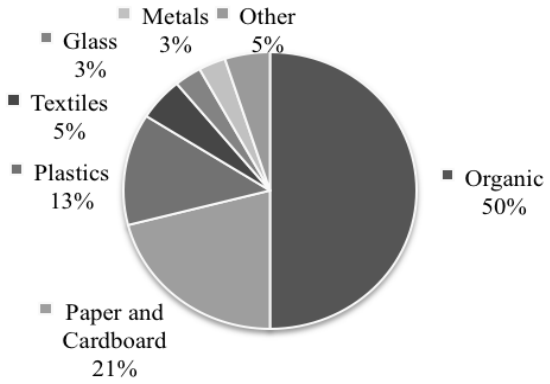

Fig. 1: Composition of MSW Stream in Kuwait [2]

1.2.2. The current waste management system in Kuwait

At present, all wastes are randomly dumped into landfills without considering safety and environmental precautions from the point of collection and transportation to the last step of final cover in a landfill [2].

At present, the first steps are the collection and transportation of waste, which is done once or twice a day by 4-5 workers by means of trucks [2]. These steps involve poor practices by municipalities and contractors, because no segregation of materials is performed and the waste is delivered directly to the disposal sites [2].

Finally, the collected waste goes to recycling, treatment or disposal. Unfortunately, there are only a few recycling companies in Kuwait, and these deal with a small portion of the discarded materials. The other, larger, portion of the waste goes to treatment or disposal, depending on the type of material being dumped [2].

1.2.3. Landfills in Kuwait

Currently, there are sixteen landfills in Kuwait. Thirteen are closed; only three are active [2]. Unfortunately, there is not one landfill that meets the criteria of a sanitary landfill. Instead, all of the waste is dumped into random holes. Landfills occupy 45.5 km^2 of Kuwaiti land, and this area is expected to increase to 60 km^2 by 2025 [2]. With this shortage of land, given that only 25% of Kuwait is available for public use and 75% is owned by the government and petroleum sectors [2], and with the growth of population and land development strategies, available open areas will be hard to find.

Selecting the right location has a huge impact on the environment, human health and the value of the surrounding areas. Dumping waste in an improper manner is a waste of money and resources and could cause problems in the cases of the AlQurain and Sabhan landfills. The AlQurain landfill is located in a residential area. The area has suffered strange and intense odors as well as the occurrence of flares due to the ignition of methane gas emissions. The government has had to address this problem by using collection and removal systems for gas and leachates [2]. The Sabhan landfill affected the nearby military installations, and this led to its closure. Since that time, it has been an unguarded area, and this has led to a large accumulation of C&D waste, tires and wood. The action plan was to open the landfill again after it had been restored.

1.3. 4R's & L Strategy

The 4 R's & L strategy is an inclusive approach tow sustainable solid waste management. It refers to the complementary utilization of several activities for the effective processing of solid waste. Integrated solid waste management includes many of these activities, such as planning, financing, collection, transportation, separation, handling, remediation and disposal of waste. The 4 R's & L strategy consists of: Reduce, Reuse, Recycle, Recover and Landfill. The main purpose of the 4R's & L strategy is to minimize the amount of waste generated as far as possible. The 4R's strategy helps to protect human health, provides a clean and safe environment, saves landfill area, and saves energy and natural resources, in addition to saving waste management costs.

1.3.1. Reduce

Reduction involves the prevention and avoidance of waste resource production. It is the easiest and most preferable option to minimize the amount of waste produced [3]. The following are guidelines regarding the reduction strategy:

- At supermarkets, buy only what is needed, in bulk, without packaging, and use your own bags when shopping. Avoid disposable goods, such as paper plates and cups.

- At work, use emails instead of printing; print on a reduced scale, and use both sides of the paper. Rent, lend, and borrow instead of buying.

If reduction is not feasible, then reuse.

1.3.2. Reuse

Reuse refers to using items repeatedly, either for the same purpose or for other purposes. Reuse does not necessitate reprocessing. Therefore, it has low energy requirements [3]. Here are some guidelines regarding reuse strategy:

Donate old items, use rechargeable batteries, and reuse glass products as containers and vases.

If reusing is not feasible, then recycle.

1.3.3. Recycle

Recycling means reforming new products by reprocessing waste materials. It saves non-renewable natural resources, conserves landfill space, reduces air and land pollution by reducing greenhouse gas (GHG) emissions and saves energy. Table 2 below lists recyclable and non-recyclable materials.

Table 2: Recyclable and Non-recyclable Materials [4]-[7].

Material	Recyclable	Non-recyclable
Plastic	Types: #1 (PETE), #2 (HDPE), #4 (LDPE), and #5 (PP)	Types: #3 (V), #6 (PS), and #7 (OTHER)
Paper and cardboard	Junk mail, magazines and catalogs, office paper, envelopes, books, receipts, paper bags, newspaper, cardboard boxes, paper egg cartons.	Paper plates, cups, towels, napkins, carbon paper, diapers, facial tissue, pads, stickers, waxed papers, waxed containers, photographs, milk or ice cream containers, frozen juice containers.
Glass	Glass jars and bottles.	Light bulbs, window glass, glassware, mirror.
Metal	Food and beverage cans, aluminum foil and trays, scrap metal	Paint cans, aerosol cans

1.3.4. Recover

Recover refers to converting non-recyclable waste materials into energy or useable materials, such as compost. Non-combustible materials, such as glass and metals, cannot be recovered; hence, they are sent to landfill to be disposed of in a sanitary way.

1.3.5. Landfill

The least-favored option is landfilling. Non-recyclable, non-combustible materials are sent to the landfill to be disposed of in a sanitary way. The landfill mentioned is a sanitary landfill that is composed of many systems, such as a gas collection and control system, a leachate collection and removal system, and the final cover system [8].

2. Methodology

2.1. Questionnaire

A questionnaire was distributed to a population sample with different ages and education levels and living in different areas and dwelling units in Kuwait. The objective of this questionnaire was to measure the level of awareness in society regarding waste and environmental issues and to take into consideration the types of actions and programs that should be established to raise people's awareness. The questionnaire showed that 51% of the respondents in the sample do not recycle their waste.

3. Action Plan

3.1. Waste Size

A forecast has been made to estimate future demands in order to design the plants ccordingly. The forecast is based on data collected from the Kuwait central statistical bureau from 2001-2012 [1]. The prediction was obtained using best-fit linear regression.

Linear regression shows a very good fit for such data. The amount of waste produced increases at a nearly constant rate each year. The R^2 value for MSW is 0.9066, which indicates a good linear relationship between values. The results for 2025 and 2040 are shown Table 3.

Table 3: Forecasting Results

Year	Population solid garbage (tons/year)	Construction waste (tons/year)	Organic	Paper & Cardboard	Plastics	Glass	Metals
2012	1,425,022	5,023,465	652,517	214,750	113,930	86,783	56,288
2025	2,315,083	7,509,757	1,157,541	486,167	300,961	140,988	69,452
2040	3,330,484	10,141,825	1,665,242	699,402	432,963	202,826	99,915

3.2. Design of the Plants

Table 4 summarizes the design of the seven recycling plants in addition to the sorting plant.

Table 4: Plants Design

Plant		Plastic	Paper	Glass	Metals	Organic waste	C&D	Tires	Sorting
% from total MSW		13	21	3	3	50			
Total tons/hour produced		62.7	101	29	29	241	1564.5	2.775	462.7
% Recycled		50	80	90	90	95	90	95	
% Recycled from total MSW		6.5	16.8	2.7	2.7	47.5			
Machine Capacity, tons/hour		31	81	26	26	229	1408	2.65	462.7
Working Hours		16	16	8	8	16	16	8	16
# of Shifts		2	2	1	1	2	2	1	2
# of lines	2025	5	5	1	1	1	3	3	10
	2040	7	7	2	2	2	4		

As is made clear in the design, the total proportion of recycled MSW will be 76.2%. The remaining 23.8% of MSW will be sent to the landfill. A total of 95% of the waste tires will be recycled, and5% will be landfilled. For the C&D waste, 90% of the waste is recycled, whereas the remaining 10% will be sent to a landfill specially designed for this type of waste.

3.3. Collection and Transportation

The plan for collection and transportation covers aspects including the location of the industrial city, the collection methods, the location of the transfer stations and the transportation methods.

The collection and transportation processes are interrelated. They play a major role in increasing the productivity and efficiency of the entire plant system. The transportation system is considered one of the main components of the design. Because roads in Kuwait are often congested, there must be a cost- and time- based plan to utilize these roads and highways. The planning of these operations is a critical case because it is governed by constraints such as government rules and regulations, the cost and availability of resources and the location of the industrial city.

3.4. Location

The industrial city will be located in an industrial area located in the middle of the state of Kabd in Kuwait so that the plants will be far from the city and residential areas, thus reducing the pollution to the city

and public disruption. Moreover, the availability of land at Kabd and its location in the center of the three active landfills facilitate access and the delivery of waste to the plants.

3.5. Collection Methods

Our suggested method for the collection process is the same as the current method, which is used by private firms that contract with the city government to collect the waste from all regions in Kuwait and to deliver it to the active landfills. This option is efficient, economical and makes the management efforts easier and more flexible.

3.6. Transfer Stations

The second operation after waste collection is transporting waste to the transfer stations. Transfer stations are the intermediate points between the collection of solid waste and transportation to recycling and disposal facilities [9]. In the case of the industrial city transfer, these stations are considered to be the three current active landfills (South 7th Ring road, Al-Jahra and Mina Abdullah).

The purpose of the waste transfer stations as described by the USEPA is to reduce the long distances of waste shipment and to lower the cost of transportation to disposal sites [10]. At these stations, the collected waste will be discharged into large trucks, containers or dumpsites where there will be vehicles to transfer the waste to the disposal sites. The advantages of the transfer stations can be summarized as follows: saving transportation cost by reducing the distance to disposal facilities, lower maintenance costs and fuel consumption, reducing traffic volume and air pollution and enabling scanning and segregation of the materials [9].

3.7. Transportation Methods

The third and last operation before recycling and disposal is transportation. Selecting a suitable method requires an understanding of the following:

1. The distances between the transfer stations and the city are approximately 45 km, 87 km and 55 km for the South 7th Ring Road, Al-Jahra and Mina Abdullah landfills, respectively.
2. Transportation should be controlled to achieve a constant rate of waste flow to the plant and to avoid leakage of raw materials from the transferred solid waste.
3. The time required for the collection and transportation of solid waste should not exceed either the period of time for the waste to rot and start releasing odors or the period for fly breeding (to avoid disease transmission) [11].

Trucks are chosen to be the transportation method due to their availability, the low price of fuel in Kuwait and the short distance between the waste resource and the plant's location.

3.8. Economic Effect

After calculating all the required costs, it was found that the total capital cost is $ 240,000,000 USD, while the total operating cost is $ 55,000,000 USD per year. However, the total revenue is $ 137,000,000 USD per year. This means that the payback period is 9.5 years from the start of the project.

The internal rate of return (IRR) must be greater than the minimum attractive rate of return (MARR) to consider the project as a good investment. In this project, the IRR value of 12% is greater than the MARR value of 10%, so this project is acceptable and a good investment.

4. Conclusion

The study showed that Kuwait suffers from a poor waste management system. Applying an ISWMS, which focuses on finding alternatives to the current disposal methods, could remedy most of the waste management problems. Through this study, it was found that 76% of waste in Kuwait could be recycled, whereas only 24% would be sent to a sanitary landfill. The yearly revenue from selling the raw materials would be equal to $ 137 million USD, and the estimated total profit of the project at the year 2040 is $ 450 million USD, with a payback period of 9.5 years from the date of initiation of the project. Therefore, implementing an ISWM action plan could achieve financial and environmental benefits.

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