Chapter 11
Waste Management in Lebanon—Tripoli Case Study

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Abstract Lebanon appears as the bad student in solid waste management (SWM) in Middle East Region, varying techniques of SWM is currently practiced in different parts of the country, a comprehensive approach to SWM in Lebanon is still now virtually absent, slow burning and uncontrolled dumping on hillsides and seashores are still common methods practiced for solid waste disposal. Except SWM in the Greater Beirut Area (GBA), solid waste continues to be managed in a manner that is not protective of either human health and/or the environment. Even in the extended GBA, serious questions are raised about the policy commitments to promoting and eventually requiring sustainable and environmentally friendly SWM practices. Tripoli (second city and capital of North Lebanon) is facing an environmental disaster; the actual landfill is over saturated and can collapse in any moment causing dangerous damage in the environment. Landfill must be closed in 2012, but continue to dump waste in reason of lack an alternative new site. Certainly, the trend will be changing and there will a great deal of effort to develop integrated SWM systems for most areas in Lebanon, particularly large urban areas. These efforts center on the construction of controlled sanitary landfills in combination with sorting, recycling, and composting facilities or waste-to-energy systems (incinerator or biological anaerobic plant).

Keywords Lebanon · Solid waste management · Landfill · Tripoli

11.1 Introduction

Lebanon population are about 5 million people that produce around 2 thousand tons of municipal solid waste (MSW) per year, while the composition of the wastes is in majority organic (near 55%). However, the organic matter is varying from urban to rural areas and from summer to winter as well [1]. Paper/cardboards and plastics constitute a significant proportion, with glass and metal contributing largely too, high moisture content is also prevalent in wastes, often exceeding 65%. It is considered

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Table 11.1 Municipal solid waste generation by Mohafazat

Mohafazat	Tons/day	% of generation
Mount Lebanon	2250	40.2
Beirut	600	10.7
North Lebanon	1000	17.9
Bekaa	750	13.4
Nabatiyeh	350	6.3
South Lebanon and Nabatiyeh	650	11.6
Total	5600	100.0

Source SWEEP-NET [1], Country Report on the Solid Waste Management in Lebanon, giz

that the MSW generation per capita varies from around 0.7 kg/p/d in rural areas to around 0.85–1.1 kg/p/d in urban areas, with a national weighted average estimated at around 0.95 kg/p/d [2]. The foreseen increase in waste generation is estimated at an average of 1.65% across the country; this growth is however highly unevenly distributed.

Waste disposal is particularly difficult in Lebanon because of its rugged terrain and limited surface area. Lebanon currently produces about 5600 tons of municipal solid waste (MSW) per day (see Table 11.1), composed of about 52.5% organic matter; 36.5% paper, cardboard, plastic, metal and glass; and 11% inert and other materials [1]. Waste is currently disposed of as follows: about 50% in uncontrolled dumpsites (about 940 dumpsites); about 35% in sanitary landfills (Bourj Hammoud, Costa Brava, and Zahle); and the remaining waste (about 15%) undergo material recovery, sorted into recyclable or reusable materials (paper and cardboard, plastic, metal, glass, etc.) or converted into organic soil compost in approximately 50 facilities across the Lebanese territories [2]. Despite its importance in reducing landfilling, energy recovery is practically not carried out in these existing facilities, except Saida and Naameh (closed in 2017).

In addition to MSW, Lebanon produces about 50,000 tons of hazardous solid waste each year: hazardous industrial chemical waste; electronic waste; expired solid drugs and materials; healthcare waste (hazardous non-infectious waste, waste requiring special management, hazardous infectious waste, etc.); used oil; used tires; used batteries; persistent organic pollutants from the energy sector or other sectors; various types of sludge, etc. [3]. Also, there are other wastes such as solid waste from the olive oil industry [4], slaughterhouse waste, construction and demolition waste, and bulky refuse/waste.

Environmentally sound treatment of hazardous solid waste and other waste is also non-existent, as most are disposed in a haphazard manner, with the exception of a portion of healthcare hazardous infectious waste [5], that is treated in accordance with the provisions of Decree 13389/2004, and some types of hazardous waste that

are exported in accordance with the provisions of the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (Law 389/1994), [6].

Over the past 20 years, despite considerable progress in shaping its legal and institutional framework and providing substantial public funds for financing its infrastructure after the war, Lebanon is still at an early stage of its transition to environmental sustainability [7]. Contrary to the municipal solid waste collection services, whose improvements were both effective and equitable over the years, the solid waste treatment and disposal subsector continue to face stern challenges. Lebanon experienced a string of SMW plans, such as transforming waste-to-energy (WTE) in 2010 in Saida Plant (anaerobic digestion), open dumps are getting out of control; most old major dumps were not closed down properly or rehabilitated [8].

The institutional framework is quasi-absent, and cost recovery for waste disposal and treatment is zero [9]. SWM services are provided by the private sector through regional solid waste contracts which increased regional monopoly powers and reduced competition and therefore efficiency [10].

On September 24, 2018, the Lebanese Parliament endorsed the draft SWM law which has stirred controversy inside the parliament and was faced with objection from several MPs.

11.2 Tripoli Case Study

11.2.1 Solid Waste Management in Tripoli

Tripoli, the second capital of Lebanon, like many cities, suffers from the absence of the proper SWM. Proper management of solid waste relies on the proper collection and disposal of municipal solid wastes (MSW) in the landfill. Collecting MSW is the mission of a private company LAVAJET when BATCO (sister company) is in charge of the landfill operation [11]. Households do not practice formal waste separation. The collection contractor is supervised by the Council for Development and Reconstruction (CDR) on behalf of the Union of Al-Fayhaa Municipalities, UFA (Tripoli, Mina, Baddawi, and Kalamoun).

Tripoli landfill is situated along the coastline, north to the Port of Tripoli and adjacent to the Abou Ali River estuary and covers an area of approximately 60,000 m^2 (see Fig. 11.1). It started to receive waste in 1980 and in the year 2000 it was converted into a semi-controlled dump with the integration of a gas collection system and containment wall. The dump currently receives an average of 450 tons/day. It should be closed end of 2012 but unfortunately it is still receiving waste till now, it becomes a mountain fully saturated which can fall apart at any time causing an ecological disaster that Lebanon has never known [12].

For over 20 years and up till 1999, the site was being used as a "boundary-less" savage dumpsite catering to Tripoli and its surroundings. Needless to say, this situ-

Fig. 11.1 Tripoli Landfill

ation was causing an environmental catastrophe zone in terms of pollution, vectors, odor, fires, etc. In 1997, and as an initial step to solving this prevailing problem, a peripheral seaside wall was constructed to stop the expansion of the dumpsite into the Mediterranean Sea. And in 1999, UFA initiated a project to rehabilitate the site and to operate it as a controlled landfill. The Council of Development and Construction (CDR) contracted a private contractor to improve waste disposal practices and manage the controlled dump, by retrofitting it with gas extraction wells and flaring units [13].

The operation of the Tripoli Landfill includes control of incoming wastes, proper waste placement, and compaction, application of daily cover, biogas flaring and limited leachate control (both stopped in 2013), this operation has alleviated the once prevailing adverse environmental conditions. The Tripoli Landfill receives wastes from Tripoli, El-Mina, El-Bedawi, El-Qalamon cities, and north Palestinian refugee's camps at an average rate of around 450 tons/day. The piled trash had reached its maximum capacity in 1992, and that it was not possible to accept more waste, but unfortunately, up until it continues to operate with a risk of thousands of tons of trash could be to spread into the sea (see Fig. 11.2), causing an ecological catastrophe in the Mediterranean [14].

Some scavengers are allowed in the landfill by the UFA; they enter and collect their desired recyclable material from the receiving area immediately before the waste is spread in specific areas of the dump. Collected recyclables include plastic, iron, metals, and previously cardboard. Scavengers work quickly and collect what

Fig. 11.2 Sea view of Tripoli Landfill

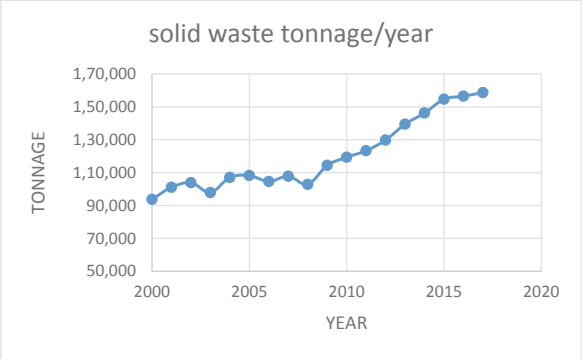
Fig. 11.3 Aerial view of Tripoli Landfill

is visible to them while heavy machinery is maneuvering around. This means that a very low percentage of incoming waste is sorted out for marketing.

For the moment, the estimated volume of waste in place is more 1.1 Million m^3 based on a review of the topographic maps, spread over a total area of 60,000 m^2. The highest point of the dumpsite is around 45 m (see Fig. 11.3), the annual volume of waste landfilled is shown in Table 11.2 [15].

Table 11.2 Disposed waste quantities for the period 2000–2017

Year	(Tones/year)
2000	93,749.74
2001	101,082.16
2002	103,886.90
2003	97,893.10
2004	107,101.96
2005	108,221.18
2006	104,631.48
2007	107,820.72
2008	102,866.54
2009	114,419.28
2010	119,371.02
2011	123,342.02
2012	129,818.09
2013	139,496.32
2014	146,270.15
2015	154,700.04
2016	156,510.00
2017	158,720.00



11.2.2 Landfill Operations

The landfill is currently operated according to the following procedure:

11.2.2.1 Inspection

Contents of the incoming refuse collection vehicles (RCV) are visually inspected to check their compliance with permissible wastes. Approved vehicles are allowed to proceed for weighing.

11.2.2.2 Receipt at Weighbridge

The weighbridge transaction includes the following:

- Identification of the RCV and the transporter;
- Origin of the MSW;
- Type of the MSW;
- Entry date and time;
- Tare weight of the RCV and net weight of MSW.

11.2.2.3 Landfilling

RCV proceed to the landfill area utilized according to the waste filling program. Contents are discharged in the designated area, spread and compacted in layers of approximately 50 cm then covered with at least 15 cm of inert soil material. Permanent and temporary access road is provided for the ability to use for transportation of the solid waste material for the required active area. After that, the transporter comes back to the weighbridge to withdraw the certification of the material disposed of.

11.2.2.4 Leachate Collection and Disposal

Leachate collection is drained into pits and was partially treated during 4 years (2009–2013) in a treatment plant. The leachate generated by the Tripoli Landfill activity was subject to a recirculation process consisting of spraying and evaporating the leachate on the compacted solid waste and recollecting the leachate through a peripheral network beneath the solid waste. However, this process has been jeopardized by the construction of the peripheral trenches as well as by the increasing height of the solid waste, where the related equipment (pumps, etc.) could not sustain such variations.

As for the leachate treatment process [16], it consists of a biological treatment process that includes (see Fig. 11.4) an aerobic digester with nitrification and anoxic denitrification; clarification; chlorination; and filtration (sand and carbon filter). Unfortunately, this treatment plant did not reach its desired treatment level as originally planned where the entering rainwater and the increasing volume and height of solid waste overwhelmed the design capacity of the plant (36 m^3/day). All efforts were taken to improve the treatment level of the plant gone without success. Therefore, part of the leachate is recirculated in the landfill itself or is discharged into the river discharging in the sea (see Fig. 11.5).

11.2.2.5 Gas Collection

Different vertical landfill gas (LFG) wells have realized across the site and connected them to regulation stations connected to the flare (see Fig. 11.6). A large capacity LFG flare (1100 m^3/h) has been procured and installed in 2009 by the contractor to replace the initially installed LFG flare (500 m^3/h) in the year 2001 to account for the increased LFG production and collection in view of the landfill closure and the installation of the final cover, which was initially planned for the end of year 2009.

The system was stopped in 2013 because the LFG wells need to be elevated vertically as waste is dumped vertically. This operation necessitates putting the wells that are being elevated off-line to avoid the air suction in the system with additional piping and connections to the reinstalled regulating stations [17].

Fig. 11.4 Leachate treatment unit in Tripoli Landfill

The failures that occurred in the outer face of the earth reinforced wall imposed some actions to avoid jeopardizing its stability, which led to increasing the level of oxygen in the extracted LFG by the flare suction unit [18].

It should be noted that the Tripoli landfill gas flare couldn't be duly and properly operated in the existing conditions that prevail in the landfill, namely the increasing height of the solid waste (more than 32 m), the peripheral trench excavated to alleviate the solid waste active pressure on the peripheral wall, the continuous operation preventing the installation of the final cover, etc. Indeed, the extracted gas sent to the flare should be relatively pure in order to ensure proper operation of the equipment, thus, in the existing conditions, the extracted gas is mixed with air due to the trenching that was done for stability purpose.

The gas flare can be duly and properly operated continuously once the peripheral trench is backfilled, gas wells upgraded to allow for the actual increasing height that the landfill has reached, landfill closure date is known, and the final cover is placed.

For the moment, the biogas released is confined in the landfill, and it is considered as a time bomb and could be at the source of an accidental big fire with the bad consequences to the health and the environment.

Fig. 11.5 Leachate discharged to the Abou Ali River

11.2.2.6 Peripheral Wall

The waste mountain stretches 45 m high from the surrounding terrain. It is an enduring eyesore and health threat to residents and tourists. The environmental repercussions are severe; occupational hazards related to incoming uncontrolled waste, possible recurring waste slides into the Mediterranean Sea with the threaten to Natural Marine Reserve of Palm Island located at 10 km.

In order to avoid the expansion of the dumpsite into the Mediterranean Sea, a peripheral seaside wall was constructed in 1999. It consists of concrete blocks, geotextile, and geogrid materials (see Fig. 11.7); the backfill is composed of sandy gravel and clay soil. The peripheral wall of the landfill is monitored via topographic surveys, which are conducted on a monthly basis using 11 stations about the middle of the peripheral road at the top of the wall and 10 stations on the concrete hollow blocks forming the facing of the wall.

A structural failure in the peripheral wall occurred many times since 2011, where parts of the reinforced earth wall collapsed along due to sliding of the waste mass. Whereas other parts within this section remain unstable, although the blocks which constitute the facing of the wall and some of the fill have collapsed, no shear failure is observed in the reinforced fill massif. Preventive measures by repairing some portions of the wall in particularly adjacent to the river have regularly undertaken

Fig. 11.6 Gas collection network in Tripoli Landfill

to avoid any potential sudden burst. Note that the activities adjacent to the landfill, including land reclamation (north of the site: future new Special Economic Zone) and stone crushing and vibration screening activities (south of the site: private illegal exploitation), are expected to have contributed in the collapse of the waste mass.

In April 2018, two sections of the peripheral wall collapsed in separate incidents warned of an impending environmental disaster, fortunately no trash had fallen from the dump as a result of the cracks, only some bricks have fallen from the site. In the picture (see Fig. 11.8), we can show bricks missing from the wall, but the waste appeared compact and contained between layers of permeable liner. To avoid an environmental catastrophe, an additional wall was built to reinforce the side that partially collapsed (see Fig. 11.9).

The landfill has to be closed in the year 2010, for saturation conditions, but it continues to operate because of the non-finding alternative site, despite the existing danger (breakdown, collapses, fire, …), the discharge of leachate to the sea or the Abou Ali river, and the non-extracted and incinerated biogas generated [19]. The extended date of closure was due on the end of the year 2012, but the landfill is still operational until today.

Fig. 11.7 Part of the peripheral wall in Tripoli Landfill

11.2.3 Sorting and Composting Plant

A sorting and composting plant was built by the Office of the Minister of State for Administrative Reform (OMSAR) with the financial support from the European Union near the dumpsite area for a capacity 420 tons/day. But few weeks the plant started, the Union of Al-Fayhaa Municipalities (UFM) stopped him for the residents' complaints about its foul odor in the city, the weak recycled percentage (less than 5%) and the refuse of agriculture to use the compost for its bad quality (see Fig. 11.10).

After site inspection, it was clear that troubleshooting in the composting process and the sorting line were found and particularly in the biofilter and the maturation phase of compost.

For the moment, OMSAR and UFA work together to find a solution to solve this problem by introducing technical modifications to the facilities.

Currently, incoming waste undergoes no sorting whatsoever, the only form of sorting is done by the scavengers who are allowed, by authorization from the UFA, to enter the site and collect their desired recyclable material from the receiving area immediately before the waste is spread in specific areas of the dump.

Collected recyclables include plastic, iron, metals, and previously cardboard. Scavengers work quickly and collect what is visible to them while heavy machinery

Fig. 11.8 A partial collapse in the peripheral wall

is maneuvering around. This means that a very low percentage of incoming waste is sorted out for marketing.

11.2.4 New Maritime Sanitary Landfill

In the absence of the alternative sustainable solution for the management of solid wastes in Tripoli, and in reason of the dangerous situation of the actual landfill, the Lebanese government has decided the extension into a new temporary landfill located just in front of the actual landfill by reclaiming 60,000 m^2 (see Fig. 11.11). The new landfill which contains three cells and designed for 3 years must be operational at the beginning of 2019 (see Fig. 11.12). After that, the actual landfill must be closed, and its rehabilitation start.

This new reclaim sanitary landfill is the third site decided by the government after the Bourj Hammoud (North Beirut) and Costa Brava (South Beirut) sites.

Fig. 11.9 Additional protection built in front of the collapsed peripheral wall

11.3 Future Management Policy of Solid Waste

Uncontrolled dumping and improper waste handling cause a variety of problems, such as contaminating water, attracting insects and rodents, and increasing flooding due to blocked drainage canals. Also, it may result in safety hazards from fires or explosions. Improper waste management also increases greenhouse gas emissions, which contribute to climate change [20].

Therefore, Lebanon should adopt an efficient solid waste management system, based on preventing waste, recycling, composting, and finally disposing of the remainder. Waste prevention strategies include using less packaging, designing products to last longer, and reusing products and materials (such as stuffing used textiles into mattresses).

Recycling involves collecting, reprocessing, and/or recovering certain waste materials (metals, glass, papers, and plastic) to make new materials or products. As organic materials cannot be recycled, and as they are rich in nutrients, they can be converted into soil additives in a process called composting. However, the process of recycling and composting is heavily dependent on separation at source, whereby households should divide their wastes into different kinds, before being collected.

Finally, waste that can be neither prevented nor recycled or composted can be placed in a properly managed landfill to produce energy. These wastes undergo pro-

Fig. 11.10 None conform compost produced in Tripoli composting facility with leachate in open air

Fig. 11.11 Location of the new temporary landfill in Tripoli

Fig. 11.12 Reclaim to build a new temporary sanitary landfill in Tripoli

cedures which include combustion, gasification, pyrolization, anaerobic digestion, and landfill gas recovery to produce energy, what is known as waste-to-energy (WTE) process.

Finally, a roadmap for Lebanon to treat the waste may include the following. First, the citizens should be encouraged to participate in waste management by splitting their wastes into inorganic (glass, plastic, paper, textile, electronics), and organic. Another process of separation should occur after collection, to ensure appropriate segregation of domestic wastes. The recyclable refuse is then sent to a recycling plant, and the organic waste gets composted. Finally, the remnants get disposed of in sanitary landfills, where methane gas could be recovered and used to produce energy. Considering the implementation of such a process, Lebanon could be capable of transforming its waste from a burden on the government to a source of revenue, originating from the sale of recyclable materials and power generation.

11.4 Conclusions

In Lebanon, there are many difficulties to apply a good solid waste management practices some of them are:

- Increase in the population,
- Migration of the population from rural to urban areas,
- No precise studies are made on the right technologies,
- No legal framework and poor law enforcement,
- Contradiction in policies,
- No serious actions to implement incentives,
- No solo administration is dealing with this file,
- No financial act to recover the cost.

That's why Lebanon still remains in the labyrinth of anarchy. The government should take a decision for SWM with the techniques that should be considered regarding the appropriate sites for those techniques and the same time decide funding and cost recovery for them.

11.5 Recommendations

In Lebanon, solid waste management remains an environmental major problem, practices currently in use are decided at the last day and are put in front of the fait accompli and whatever the cost that may arise and the impact on health and the environment.

In the absence of a sustainable solid waste management policy, the consequences of these practices will be disastrous for the future of country. Public authorities must take into consideration the fact that the image of Lebanon is increasingly downgraded and the protection of the environment is no longer the priority for the country.

An extensive awareness-raising program on good practices in solid waste management for all citizens is needed, it is urgent to put in place preventive measures that consist in adopting eco-responsible behaviors and attitudes that make it possible to put in place sorting, selective collection, and recovery of wastes.

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