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Research Article

Solid Waste Management in Lebanon: Challenges and Recommendations

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Successful waste management plans require accurate data about the nature and composition of waste. Despite the high content of organic (52%) and recyclable (37 %) materials in waste stream, only 8% and 15% of solid waste are recycled and composted respectively. Unfortunately, 48% of the waste are disposed in sanitary landfills. Dumping of waste and open burning is predominant outside Beirut and Mount Lebanon. Adequate treatment is unavailable for wastes produced by slaughterhouses, industrial premises and healthcare centers. Corruption, lack of human resources and suitable facilities and inadequate technical skills are responsible for inefficient municipal solid waste management. This paper aims at determining the current practices of municipalities in terms of segregation, collection, treatment and final disposal of solid waste. It also considers key policy challenges and recommendations for improving the municipal solid waste management system.

Key Words: Solid Waste Management, Recycling, Composting, Incineration, Landfill.

INTRODUCTION

Waste generation in Lebanon has increased significantly during the past decades. This is mainly due to the rise in community living standards, urbanization, immigration of Syrian refugees, and increasing in population levels (Cohen, B. 2004; MOE, 2014). Solid waste management (SWM) is critical in protecting environment and ensuring human health. Therefore, new strategies are needed to deal with the waste Lebanese produce today to prevent it from creating problems for next generations. In the last few months, Lebanon witnessed a waste management crisis which results in the scattering of satellite landfills and incineration sites throughout the country, with grave consequences on health, economy and environment (Sara, 2015; Giusti, 2009; Naharnet Newsdesk, 2016; Coffey, 2010). For the first time, dioxin and Dibenzanthracene compounds were identified in air in Lebanon (Massoud 2016). These toxins have the potential to raise the lifetime of cancer risk (Aderemi, 2012; Mazz, 2015; Thamaraiselvan, 2015) and may cause lasting ill effects on human health and environment (Khairy, 2009).

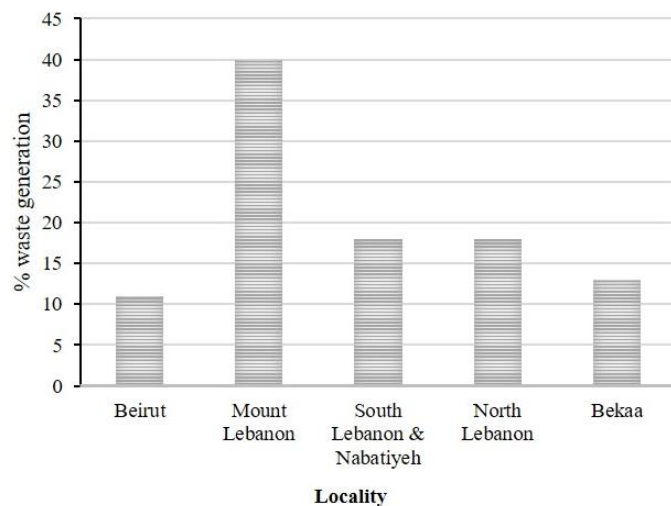
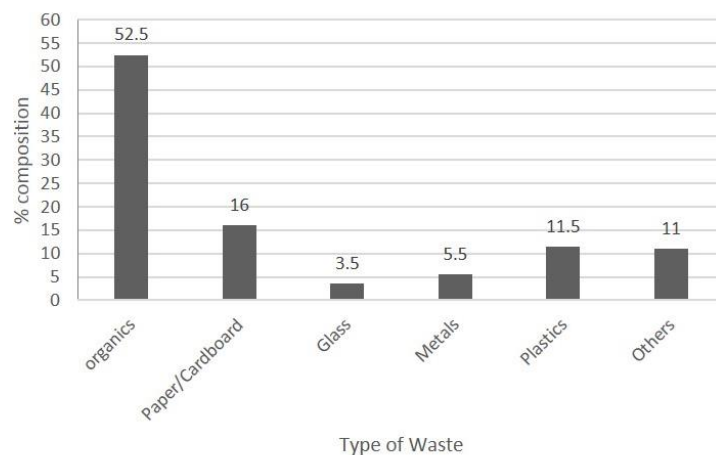
Although Lebanon practiced a string of SWM plans (Halldin, 2010; MOE, 2011) over the last 20 years, SWM has remained a complex task. This is due to deficiency in skills of modern SWM practices (Boadi, 2005; Vitorino de Souza, 2017), lack of awareness on the threats of unsustainable waste management practices (Henry, 2006), and poor Government support (Konteh, 2009). Private sector has failed to shift from high percentage of disposal to recovery of both energy and materials (CDR/LACECO, 2011).

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Table 1: Background information about waste in Lebanon (MOE, 2014)

Population	5,600000 Lebanese + 2500000 refugees
MSW Generation	2.04 million tons
- Urban Areas	0.95-1.2 Kg/day
- Rural Areas	0.8 Kg/day
MSW Generation Growth	1.65 % per year
Medical Waste	25040 tons/year
Industrial Waste	188850 tons/year
Slaughterhouses Waste	40000 tons/year

**Figure 1:** Waste generation per locality (GIZ, 2010).**Figure 2** Waste composition in Lebanon. (MOE, 2014; Massoud, 2016)

On the other hand, municipalities are facing main problems such as lack of organization, and financial resources (Parthan, 2012), Consequently, high percentage of Lebanon's solid waste still ends up in landfills and open dumps (MOE, 2011). The current waste problem could be resolved by adopting an integrated sustainable waste management strategy. Thus, the main objectives of the study are to determine the current practices of municipal SWM in Lebanon in terms of segregation, collection, treatment, and final disposal; assess the level of services and allocation of financial and human resources in SWM; and identify key policy challenges and recommendations for improving municipal SWM in Lebanon.

MATERIALS AND METHODS

Quantum and Nature of Solid Waste

The properties of municipal solid waste (MSW) collected from different places in Lebanon depend on many parameters such as consumer patterns, food habits, the cultural traditions of citizens, lifestyles, climate, and economic status. As the cities expand, average per capita waste generation increases. Waste generation is 1.05 Kg per capita per day in Lebanon amounting to about 2.04 MT of waste annually (Table 1). Also, lifestyle changes are leading to the use of more packaging materials and as

such waste generation is increasing by about 1.65 % per capita per year (MOE 2014). Lebanon is divided into five localities: Beirut, Mount Lebanon, South Lebanon and Nabatiyeh, North Lebanon, and Bekaa. Contribution of each district to the total stream of solid waste is presented in Figure 1.

Various research studies have been conducted on the composition of the MSW stream in Lebanon since 1995 (Figure 2) (MOE, 2011; Massoud, 2016). Analysis of waste composition indicates that the highest waste fraction is organic matter (52%), followed by papers and cardboards (16%), plastics (12%), others (11%), metals (6%) and glass (3%). The high organic content suggests the frequent collection and removal, as well as good prospects for organic waste resource recovery. The content of major reusable and recyclable materials (i.e., plastic, paper and paper products, metal and glass) comprised 37% on average. It is also notable that the composition of municipal waste varied greatly among different locations in Lebanon. Organic content at the national level (52 %) may be lower than in Beirut (63%) because people feed some of their organic wastes (vegetable cuts, fruit remains, etc.) to their domestic animals in rural areas. MSW makes up about 89 % of the total solid waste stream generated in Lebanon (Figure 3).

The main sources of MSW are households, commercial establishments, street markets, street cleaning operations,

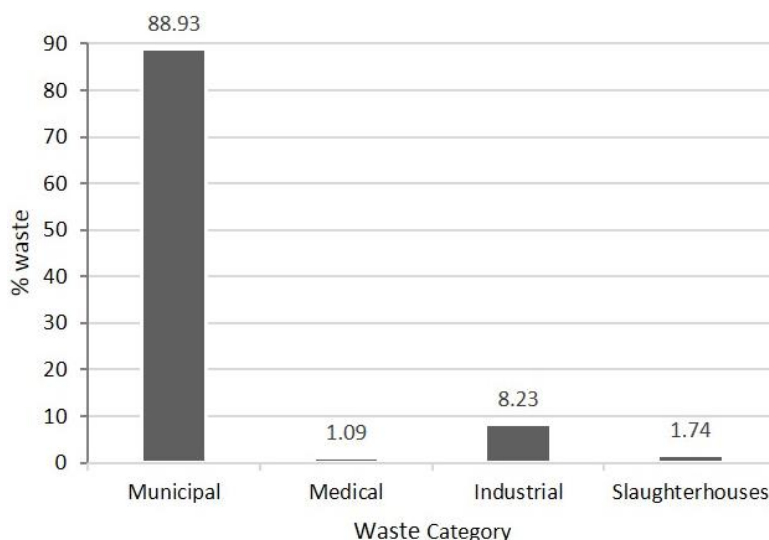


Figure 3 Waste categories in Lebanon. (MOE, 2014)

Table 2: Duties of different stakeholders (MOE, 2011; Massoud, 2016)

Stakeholder	Main Responsibilities
Waste Management Board	Developing waste strategy and authorizing waste management plans
Ministry of Environment	Initiating waste management standards and guidelines and implementing waste management programs
Ministry of Interior and Municipalities	- Participation in the National Strategy and plan and implementation of local waste management plans - Establishing/ implementing waste management programs
Municipalities	- Participation in the National strategy and plan through the Waste Management Board - Proposing and implementing local waste management plans for non-hazardous municipal waste - Establishing / implementing waste Management programs - Management of waste collection
Council of Development and Reconstruction	- Assistance in procurement of WM projects upon request - Assistance in the development of WM plans upon request
Private Sector / the Public	- Abiding by laws, regulations and guidelines on waste management - Prohibition of littering, illegal dumping and burning - Participation in the National strategy and plan through the Waste Management Board - Participation in the development and implementation of local waste management plans - Participation of facility and generator management plans

and fields' trimming. As far as the industrial waste is concerned, about 22,000 industrial companies produce a wide range of solid wastes which contribute to about 8.23 % to the total solid waste stream in Lebanon (GIZ, 2010). Non-hazardous wastes (packaging, Styrofoam, wood pallets, food residues, etc.) comprise 98.2 % of the industrial waste stream. The remainder fraction however is potentially hazardous, as defined by the Basel Convention (www.basel.int).

The composition of Lebanon's industrial waste is poorly documented and no plants are available for industrial waste treatment. In the absence of a well-defined legislation and more stringent controls, most of the industrial and hazardous wastes are mixed with the municipal wastes. Additionally, wastes produced by slaughterhouses contributes to 1.74 % of total waste generation (MOE, 2011). Furthermore, waste stream composes of 20 and 79.8 % of infectious and non-infectious healthcare wastes respectively.

Finally, there are currently no facilities for recovering used tires. Within Sukleen's service area, used tires are collected as part of the bulky waste stream and stored at the warehouse. A small portion is then resold to tire recycling customers while the remaining portion is shredded and sent to Bsalim landfill to be used as inert material (GIZ, 2010). Outside Sukleen's service area, used tires are either (1) stockpiled in various locations (mainly near vehicles repair shops), (2) dumped haphazardly, (3) used as solid fuels for home heating, and/or (4) burned.

Stakeholders

Stakeholders usually have different interests and play different roles (Zarate, 2008). The key stakeholders and their duties in MSW management are listed in Table 2 (MOE, 2014; Massoud, 2016). Stakeholders' involvement is a key factor for the success of SWM. Government is considered as the most important stakeholder which set up policies and the provision of SWM system. The private

contractors are also considered as essential stakeholders as well as the facility users such as: households, civil organizations, industrial and commercial sectors. The less important stakeholders are educational and research institutions, farmers, health care centers, Chamber of Commerce and Industry, recycling companies and police. MSW in main cities is mainly operated by private sector. The main roles of private sector are collection, transport, processing and disposal of solid wastes. In the capital (Beirut) and parts of Mount Lebanon, Sukleen is responsible for waste collection and street cleaning. Waste treatment and disposal are performed by SUKOMI. Waste treatment is mainly based on bailing, wrapping, transport and landfilling, with sorting and composting, and at costs which are substantially high (Mazza, 2015). In Tripoli, Lavajet and BATCO are responsible for waste collection and disposal respectively. In the city of Zahleh, the private sector is responsible for waste collection and disposal of solid waste. In Saida, the private sector built an anaerobic digester for municipal waste treatment.

RESULTS AND DISCUSSIONS

Existing Solid Waste Management System

Collection and Segregation

Collection, city cleaning, and sweeping is not performed every day except in main markets and in some residential areas. Other areas are served occasionally from twice a week to twice a month. Many areas are neglected due to the ineffectiveness and insufficiency of the service. Container service, and roadside pickup from open piles or containers are the types of collection service generally used by municipalities and private sectors.

In Beirut and Mount Lebanon, the collection of waste from curbside containers and transportation into the two sorting facilities are performed by SUKLEEN. Processing of waste at the two sorting facilities are similar. This includes weighing, manual sorting and mechanical separation of waste by trommel screen. Organics are then sent for composting at the Coral plant. Manual sorting is further practiced to remove recyclable materials. Residual waste is then baled, wrapped and transported to the Naameh Landfill (currently Costa Brava landfill). From the waste collected, around 48% goes to landfills, 15% is treated, and 8% is recycled.

Outside Beirut and Mount Lebanon, municipalities are carrying out waste management operations (collection and disposal) according to Municipal Law No. 118 (dated 30 June 1977). Some municipalities are using their own waste collection vehicles and workers and others are subcontracting the service to private sector. Waste recovery outside Beirut and Mount Lebanon is estimated

at 13% percent of the waste stream (GTZ, 2010). A number of municipalities have received technical and financial aid from international development organizations to enhance their waste management services by constructing small and medium-sized solid waste recovery facilities (GIZ, 2010). Open dumping, including riverside and roadside dumping, is practiced by many municipalities.

Transport and Final Disposal

Facilities and equipment existing in municipalities affect the effectiveness of waste transfer from primary collection to processing centers or final disposal sites. Transportation of waste from the waste storage areas to the disposal site is done by a variety of vehicles such as trucks and modern hydraulic vehicles. The percentage of MSW disposed of at landfills amounts to 48 % of the total. Problems facing municipalities at present include lack of technical support, financial constraints, problems in area selection for landfilling and strong disapproval from nearby communities. Political intervention has also been practiced in many municipalities.

In Lebanon, there are two sanitary landfills and a third landfill for inert materials in Bsalim. The three landfills receive solid waste from about half of Lebanon's population. Shredded materials and rubbles make up 89 % of the waste sent to Bsalim. Recyclable materials sent for disposal include PET, dirty plastic, tins, and cardboard (plus shredded wood and shredded tires).

Recently private sector and Lebanese authority built up the Costa Brava landfill in Ouzaai (south of Beirut) to solve the problem of MSW (Obeid, 2016). The new landfill will temporarily solve the problem of the accumulation of solid wastes in the streets of cities but it will not form a permanent and environmentally friendly solution for solid waste. Thus, garbage could start once again piling on the streets if an integrated SWM system is not considered and approved by Lebanese government. Currently, Costa Brava landfill receives around 200 tons of the 650 tons of waste generated per day in the capital. 250 tons of the remaining garbage is sent to a waste treatment plant in Sidon. Outside Beirut and most of Mount Lebanon, dumping of waste and open burning is predominant. Tons of solid wastes are disposed in the environment every year including household waste, bulky items, as well as medical, industrial, agricultural and slaughterhouse wastes.

Treatment of medical waste was principally achieved on-site at hospitals in devoted medical waste facilities. Over time, the expense and regulation of these facilities have prompted organizations to hire contractors to collect, treat, and dispose of medical waste. The proportion of medical organizations that complete their own treatment and

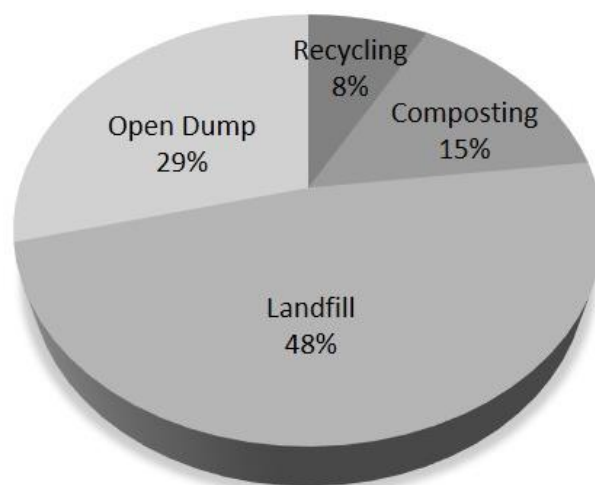


Figure 4: Percent waste recovery and disposal in Lebanon (MOE, 2014).

disposal is expected to drop. Uncontrolled and unlicensed incineration of healthcare waste continues in many hospitals releasing persistent organic pollutants and other pollutants. There are no data for expired medicines in Lebanon. Local authorities (customs, municipalities, regional health councils, etc.) occasionally find stocks of expired medicines and face major difficulties in disposing them. Ministry of Environment has prepared environmental guidelines for destroying expired goods but there are no specialized facilities that can treat the waste. In the absence of such facilities, it can be assumed that expired drugs end up in landfills and/or open dumpsites around the country.

Slaughter houses in Lebanon produces large quantities of different wastes and wastewaters. None of the slaughterhouses currently provide adequate treatment of their waste (blood, internal organs, and bones). On the other hand, wastewater from slaughterhouses is heavy in pollution and it is mixed with the municipal drain system without pre-treatment.

Resource Recovery Methods

Tight budgets and scarce resources have made municipal SWM an environmental, financial, and social burden to the municipalities. Resource recovery from managing MSW has the potential to decrease such burdens and even give profits. The composition of MSW in Lebanon showed organic materials and paper as the dominant fractions (Figure 2). Thus, recycling and composting are the most used methods for the recovery of materials from the solid waste stream (Figure 4). The most common materials that are recovered include: organics, various types of paper products, some plastics and metallic containers. The most common methods of recovery are briefly described in the following sections.

i) Recycling

The MSW composition reveals that about 37 % of the waste could be either reused or recycled, excluding

organic waste. Unfortunately, only small amount (8 %) was reused and recycled in most municipalities. It is worth noting that minority of Lebanese recover recyclable materials at source and large amounts of recyclable materials continue to be mixed with other types of wastes. Thus it is very difficult to recover recyclable materials of acceptable quality from unsegregated waste stream. When the waste arrives at the two sorting facilities, it is already in a state of decomposition, releasing leachate and foul odors. These undesirable conditions of the wastes encourage recycling industries not to buying them. In addition, there are no specific incentives to promote the recycling industry, in particular technologies that can recycle plastics (PVC and PET) and “dirty” recyclable materials. In this context, plastics, except PET and PVC, are recycled into secondary plastic products such as flowerpots and benches. “Clean” cardboard and paper are recycled by one of the few remaining paper recycling plants currently operating in Lebanon. However, these industrial plants rely mainly on informal networks of suppliers for waste paper and cardboard.

ii) Composting

The high organic content of MSW in Lebanon suggests that composting is the most efficient method to recover the organic materials. Composting provides fertilizers to farmers who otherwise have to buy chemical fertilizers at a high price. It also reduces the volume of the solid waste stream to be handled and disposed of at landfills. Some municipalities have or plan to set up community or municipal composting plants (Table 3). The Coral composting plant uses the windrows system for fermentation (12 windrows, 4-5 m wide and 2.5-3 m high), a trommel screen and a densimetric table for polishing. The composting cycle lasts around 65 to 70 days. All the compost produced are provided, free of charge, to institutions and individuals. Only about 13 % of incoming waste is processed in the Coral compost. The remaining waste fraction is baled, wrapped and hauled for final disposal at the Naameh Landfill (currently at Costa Brava).

Table 3: Municipal composting plants in Lebanon (GIZ, 2010)

Name	Capacity (t/d)	Technology
Coral	300	Windrows
Saida	300	Anaerobic Digestion
Ain Baal	150	Aerated Agitated Bed
Bint Jbeil	20	Aerated Floor
Kherbet Selem	15	Drums
Aytaroun	15	Windrows
Ansar	10	Windrows
Khiyam	10	Windrows
Ain Ebel	10	Windrows
Qabrikha	10	Windrows

Coral composting plant is facing some operational problems such as foul odors from the curing process, space limitation, proximity to residential areas, and mechanical failures. Leachate produced at the plant are treated by anaerobic and aerobic processes. The effluents from this primary treatment are then combined with the bio-filter discharge water and sent by tanker trucks to the Ghadir wastewater treatment plant south of Beirut.

Public Awareness

A critical element in SWM is public awareness, in addition to other factors such as proper legislation, strong technical support, and sufficient funding. Lack of public awareness is one of the major problems of SWM in Lebanon. Only a small percentage of the public know where their own domestic waste goes once it has been collected or how much the waste collection and disposal service costs them. Community participation has a direct effect on efficient SWM plan. Municipalities don't have awareness programs for SWM staff, and for the public. They have failed to educate citizens on the basics of handling waste and appropriate way of storing it in their own bins at the household, shop and other institutions and then disposing it in the communal storage points declared by the authorities. Therefore, the main challenge in SWM lies in alerting the public about not littering and encouraging them to dump the waste at designated points. On the other hand, households, hotels, restaurants, schools and other commercial establishments should be directed to introduce systems for segregation of solid waste. Imposing fine will not give results unless the public understand the importance of keeping the country clean. The essential barriers for raising awareness about waste management activities are:

- i. Deficiency in funds and capacity and lack of interest from key stakeholders.
- ii. Rooted cultural practices and behavioral norms.
- iii. Unsupportive legal and regulatory frameworks.

Special Waste Management

Special waste includes categories of waste slaughterhouses and industry and hazardous waste from hospitals and medical centers. Management of this

category of waste is totally different from MSW. Medical waste treatment is usually performed by incineration in hospitals in many municipalities. This involves merely burning of the waste in a chamber or open burning in the hospitals. In other municipalities, medical waste is mixed with municipal waste, and in some cases it is burned or crudely dumped. There is no appropriate system for the management of medical waste, and the staff, including medical personnel, in most hospitals are not aware of the health impacts. On the other hand, no proper slaughterhouse was observed in any of the municipalities. Dead animals are buried or dumped. The burying is done randomly at dump sites.

Drawbacks in Present MSW Services

i. Storage and Collection of Waste at Source

There is no practice of storing the waste at source and citizens have not been cultured to keep domestic, trade, and institutional bins for storage of waste at source and stop littering on the streets. There is no public system of primary collection from the source of waste generation. The waste discharged here and there is later collected by private companies and municipal workers.

ii. Low Percentage of Solid Waste Recovery and High Cost of Waste Treatment

The percentage of recovery of MSW (23 %) is very low in comparison with the amount of wastes disposed in landfills (48 %) and dumped in open areas (29%). All management options adopted across Lebanon revolve around dumping waste either in sanitary landfills or in random sites which would ultimately transform Lebanon into one large dumpsite, at a time when efficient management starts with sorting- at-source and recycling. Illegal dumping exists in Lebanon and all the countries of the region. These are effecting both the environment and citizens in a great degree. Egypt, Palestine, Morocco, Tunisia and Jordan have already set specific targets. In Lebanon, a business plan was prepared in 2011 regarding the rehabilitation and closure of open dumpsites, however no specific target has been set yet (GIZ, 2014). Currently, solid waste is not being treated and all waste is disposed in Costa Brava Landfill which will be closed in four months' time. The cost

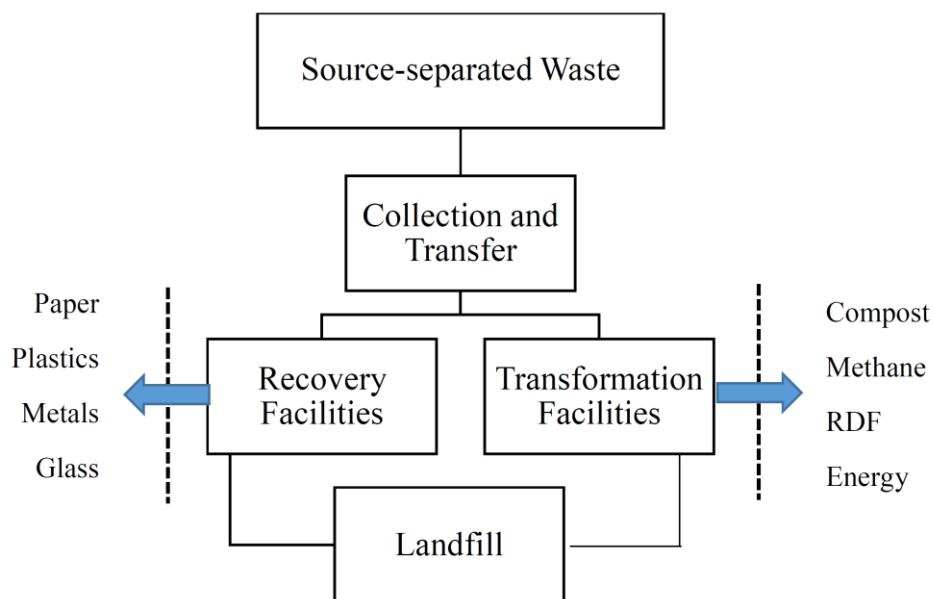


Figure 5: Integrated waste management strategies.

of waste collection and disposal amounts to roughly 120 USD per ton. This high cost prevents municipalities from living up to their responsibilities and leaves them to face wider budget deficits and failure to pay the fees required for collection and treatment.

Key Policy Challenges and Recommendations

i. Since 1994, the government contracted out waste management in Beirut and Mount Lebanon to Sukleen, which continued to collect and manage solid waste by sorting, composting, recycling, and landfilling until the expiry of its contract in July 17, 2015. Since expiry, Lebanon has challenged a garbage management problem. In the absence of governmental solutions, municipalities and citizens used primitive solutions which led to open dumps scattering throughout the country, with serious consequences on health, economy, and the environment. It can be concluded that the development of policy, strategy, and guidelines has not been effective on the ground. A national SWM policy and strategy that specifies key policy objectives, guiding principles, and an implementation strategy needs to be developed to provide clear strategic direction to local bodies. Municipalities are also encouraged to improve their SWM systems. Technical procedures need to be developed for issues such as organic composting, resource recovery technologies, and landfill development and operation.

ii. The waste in Lebanon represents a significant source of biomass, recycled materials, and energy. The large proportion of reusable and recyclable materials in solid waste offers a great opportunity for improving waste reuse and recycling. Endorsement of 3R policy significantly reduce the amount of waste to be disposed of at landfills,

thereby saving costs for final disposal and reducing public health and environmental risks. In addition, based on waste characterization (Figure 2), solid waste could be used as a potential feedstock in various waste to energy technologies such as anaerobic digestion, pyrolysis, incineration, and gasification (Figure 5) (Nizami, 2017). These technologies, if developed in Lebanon, can be able to treat around 80% of the total MSW. The remaining of MSW fraction can be recycled or disposed in landfill. This scenario requires better public awareness of the advantages of these technologies.

iii. **Strengthening Capacity of Local Bodies:** Municipalities should be in charge of collecting, transporting, treating, and finally disposing MSW. But in Lebanon, most municipalities are facing shortage of financial and human resources, as well as technical skills to effectively manage MSW. Developing the in-house capacity of the municipalities is thus essential. Municipalities that do possess MSW units are suggested to establish one and operate it with suitably qualified individuals. Municipalities should be capable of managing their recycling sites as productive units reducing overall management cost and thus allowing them to give more money for the general well-being of their communities.

iv. **Public Awareness and Participation:** Lebanon and other countries in the region such as Mauritania and Yemen through their legislation structures and practices, are not encouraging stakeholders to contribute in making waste management more sustainable for their countries. The situation is slightly better in Egypt, Algeria, and Jordan but they have still gaps in their legislative framework (GIZ, 2014). Municipalities alone can't meet the challenge of keeping towns clean and livable. Public involvement needs to be ensured through media, education, NGOs and

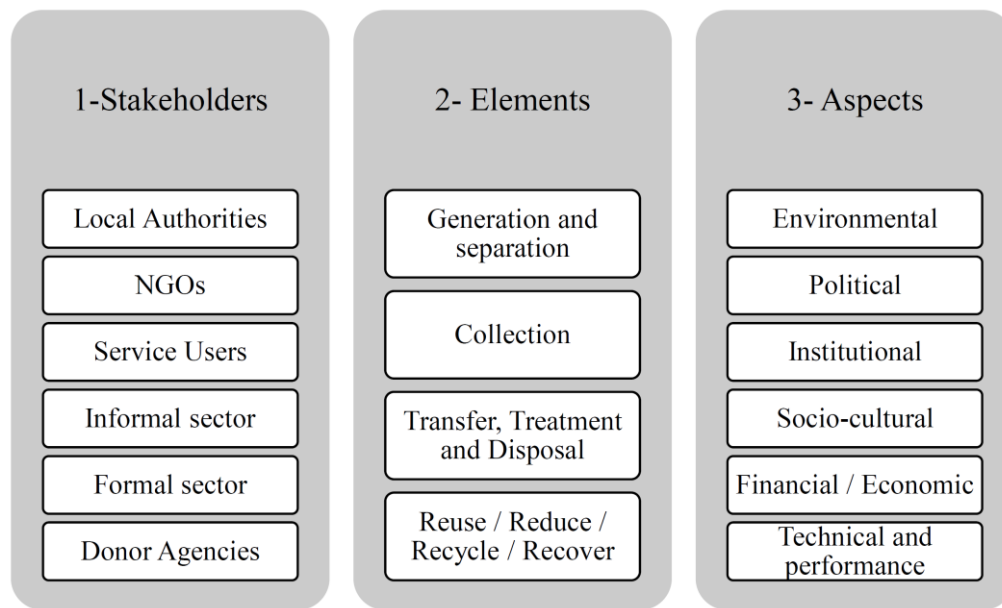


Figure 6: Integrated Sustainable Waste Management Framework (van de Klundert, 2001)

environmental campaigns to improve citizens' awareness of 3R and better SWM. Raising awareness about SWM activities can result in increases in:

- a) Use of city waste collection services by the public and private sectors.
- b) Implementation and enforcement of local waste management policies and strategies.
- c) Backing of municipalities for local-level activities.
- d) Segregation at point source and reduction of waste generation.

v. Stop the violation to the Integrated solid waste management (ISWM). Today with the current crisis, a strategy for an ISWM plan must immediately be implemented. There are three dimensions of ISWM, which need to be addressed simultaneously when designing a solid waste management system: stakeholders, elements, and aspects (Figure 6). An integrated approach is necessary from segregation at source and collection to resource recovery and landfill. Sorting garbage at home should be compulsory by the governmental laws. Resource recovery facilities may be built on the way to or near the final disposal sites so that residual wastes from recovery facilities can be brought efficiently for disposal. Recycling paper, plastic, glass, should also be applied and introduced as a law. Smaller municipalities may gradually improve their final disposal method from open dumping to engineered landfill. Incineration can be also considered as an efficient solution due to its high efficiency and low operation cost (1.5-2.5 \$/ton) (Ouda, 2016). Nonetheless, the need for treatment of air and decontamination of ashes within the incineration facilities are limiting factors for the development of this technology in Lebanon. Wastes from hospitals, plants, batteries, etc., should be listed as hazardous and submitted to a particular recycling facility or be treated in an environmentally safe manner to prevent land and water pollution.

CONCLUSIONS

The analysis of waste composition revealed that organic content is the highest fraction, making up 52% of municipal waste. Current common practice of SWM in Lebanon is landfilling. After the closure of the main landfill in Naameh, most of solid waste in Beirut and Mount Lebanon is now disposed at Costa Brava Landfill. Most municipalities in Lebanon are unable to manage MSW effectively and efficiently because of the lack of financial, technical and human resources. Government and other stakeholders were unsuccessful to implement an integrated SWM in Lebanon.

The current SWM system in Lebanon has many disadvantages such as: unorganized source reduction programs, high cost of sweeping and collection and low percentage of waste recovery. Several recommendations have been proposed to improve waste management, such as, organizing public awareness programs, which could start from the schools; increasing efforts for recycling, keeping in mind future population growth, resource recovery, strengthening capacity of municipalities and encouraging public private partnerships.

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