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Circular Economy Principles to a zero-waste Approach in Lebanon



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Colophon

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Abstract

Lebanon faces an escalating environmental crisis driven by the rising generation of waste, a challenge exacerbated by a significant lack of proactive measures. This thesis addresses the pressing need for holistic waste management strategies, aiming to mitigate the far-reaching consequences of landfill disposal on the environment, society, and the economy. The central research question investigates the key challenges hindering the efficient implementation of a sustainable waste management plan designed to reduce solid waste in landfills and mitigate associated environmental and socio-economic consequences.

Adopting a methodical approach structured around four key sub-questions, this study systematically investigates the multifaceted dimensions of waste management in Lebanon. The examination encompasses an in-depth analysis of the environmental impact of landfills, evaluating their effects on surface and groundwater quality, air and soil composition, noise pollution, and windblown litter. Simultaneously, the research delves into the socio-economic consequences, revealing correlations with public health issues, community displacement, and economic vitality.

The challenges identified span various sectors, including but not limited to, funding constraints, logistical intricacies, and a lack of sufficient policy support. These challenges underscore the complexities inherent in addressing waste management comprehensively, necessitating a strategic and collaborative approach.

In response to these challenges, the study proposes a set of recommendations designed to instigate positive change. Emphasizing the need for timely interventions, information-sharing mechanisms, policy adjustments, financial incentives, and a robust cost recovery mechanism, these recommendations seek to create a framework for sustainable waste management practices.

This research contributes a foundational understanding of Lebanon's waste management landscape, offering insights for future research and guiding the development of sustainable waste management strategies globally.

Keywords: Waste management, Circular economy, Landfills, Environmental impact, Socio-economic consequences, Lebanon.

Table of Contents

Colophon.....	1
Acknowledgments.....	2
Abstract.....	3
Table of Contents.....	4
List of Figures.....	6
List of Tables.....	6
List of Acronyms.....	7
Chapter One: Introduction.....	8
1.1 Research Background.....	8
1.2 Research Objectives.....	10
1.3 Research Question and Sub-questions.....	11
1.4 Research Relevance.....	12
1.4.1 Scientific Relevance.....	12
1.4.2 Societal Relevance.....	13
1.5 Expected results.....	15
1.6 Thesis Structure.....	16
Chapter Two: Literature Review.....	17
2.1 Municipal Solid Waste.....	17
2.1 Impact of Landfills.....	18
2.1.1 Landfills Gas.....	18
2.1.2 Landfills Leachate.....	20
2.1.3 Landfill Stability and Landslides.....	23
2.1.4 Landfill Fires.....	24
2.1.5 Socio-Economic Impact of Landfill.....	26
2.1.6 Landfill’s Impact on the Mediterranean Sea.....	29
2.2 Waste Management.....	32
2.2.1 Circular Economy.....	32
2.2.2 Solid Waste Management.....	36
2.2.3 Integrated Sustainable Waste Management.....	36
2.3 Challenges facing the Lebanese Waste Management Sector.....	42
2.4 Situation of waste generation in Lebanon.....	46
Chapter Three: Methodology.....	52
3.1 Unit of Analysis.....	52
3.2 Research Design.....	52

3.3 Data Collection.....	54
3.3.1 Literature Review	55
3.3.2 Semi-structured Interviews.....	56
3.4 Data Analysis	59
3.5 Ethical Considerations	61
Chapter Four: Results & Analysis	62
4.1 Operational Aspects:	62
4.1.1 Waste Collection & Sorting:	62
4.1.2 Operational challenges:	65
4.1.3 Data & logistics:.....	67
4.2 Environmental and Political Challenges:	69
4.2.1 Environmental concerns:.....	69
4.2.2 Political & Cultural factors:	71
4.3 Community and Stakeholder Involvement:	72
4.3.1 Community Engagement:.....	72
4.3.2 Public Awareness:	74
4.3.3 Collaboration:.....	75
4.4 Financial Consideration:	77
4.4.1 Financial Impact:.....	77
4.4.2 Financial Resources:.....	80
4.5 Area of Improvement:	81
4.6 Environmental Implications of Landfills in Lebanon	83
Chapter Five: Discussion & Recommendations	88
5.1 A Model Focused on Household Participation	88
5.2 Reevaluation and Implementation of Policies and Regulations.....	90
5.3 Financial instruments to a recovery-cost mechanism	93
5.4 A Sustainable Approach to Landfill Management	95
Chapter Six: Reflection and Conclusion	97
6.1 Conclusion.....	97
6.2 Reflections and Limitations	99
References:.....	102
Appendix A: Interview Questionnaire (English Version).....	119
Appendix B: Interview Questionnaire (Arabic Version)	123

List of Figures

- Figure 1:** The distribution of the Lebanese population across the country's provinces
- Figure 2:** United Nations' 2015 SDGs
- Figure 3:** Leachate collection system
- Figure 4:** The overview of Bourj Hammoud's landfill in the Mediterranean Sea.
- Figure 5:** The “5R” Framework
- Figure 6:** The Circular Economy diagram from Ellen MacArthur Foundation’s vision
- Figure 7:** The waste hierarchy diagram.
- Figure 8:** Design for an ecobricks circle planter
- Figure 9:** Ecobricks bottle sample
- Figure 10:** Lebanon's Population Landscape
- Figure 11:** SWM types in Lebanon
- Figure 12:** The Lebanese waste composition
- Figure 13:** The Waste composition in the Greater Beirut & Mount Lebanon.
- Figure 14:** Four-Stage Research Plan
- Figure 15:** The geographical locations of the interviewed facilities in Lebanon.
- Figure 16:** Hierarchical Coding Scheme: Groups and Subgroups
- Figure 17:** The informal sector's contribution to shaping supply chain systems through the integration of circular economy principles
- Figure 18:** The Bourj Hammoud's landfill near the Sea in the 2000s.
- Figure 19:** A map showing the location of the Tripoli landfill.
- Figure 20:** The primary water reservoirs in Lebanon.
- Figure 21:** Frequency of Interviewee stating the challenges in their discussions
- Figure 22:** Layers of governance

List of Tables

- Table 1:** Chapter’s Structure Overview
- Table 2:** The percentage of waste generation in each governance.
- Table 3:** Number of interviews in each sector
- Table 4:** List of Interviewees

List of Acronyms

Abbreviation	Term
SW	Solid Waste
SWM	Solid Waste Management
ISWM	Integrated Solid Waste Management
MSW	Municipal Solid Waste
MSWM	Municipal Solid Waste Management
SSWM	Sustainable Solid Waste Management
HSW	Household Solid Waste
GHG	Greenhouse Gas
NMOCs	Non-methane Organic Compounds
PPP	Public and Private Partnerships
SDG	Sustainable Development Goals
GPS	Global Positioning System
NGO	Nongovernmental Organization
EU	European Union
EEA	European Environment Agency
UN	United Nation
UNDP	United Nations Development Programme
MoE	Ministry of Environment

Chapter One: Introduction

1.1 Research Background

Lebanon is a small country located in the eastern Mediterranean, with a population of around 6 million people (Moultonborough, n.d.). Over the last few years, Lebanon witnessed a huge increase in waste production. This increase can be connected to population growth, industrial development, and waste generation, the increase in single-use items, changes in the local living norms, and the growing number of Syrian refugees residing in Lebanon (MOE, 2014).

Figure 1 illustrates the diverse distribution of the Lebanese population across different geographical regions. These population variances among the provinces will result in varying levels of waste generation in each area. Moreover, there might also be different types of waste in different areas due to different socio-economic classes or different industries. Per capita generation may also be different depending on income levels, further contributing to the complexity of waste patterns in Lebanon.

The genesis of Lebanon's solid waste management (SWM) crisis can be traced back to 2015, a pivotal year marked by the closure of the Naameh landfill, which had been the primary waste disposal site for over two decades (Strassmaier & Nassif, 2016). Positioned to the south of Beirut, this landfill had functioned as the principal waste disposal solution for the city and its neighboring areas (Kumarasamy, n.d.). However, the closure of the Naameh landfill, occurring after operating for eight years beyond its intended lifespan and receiving waste seven times its original estimated capacity of 2 million tons (Sawya et al, 2022), transpired without the identification of a viable alternative site. Consequently, this lack of an alternative site led to the accumulation of waste on the streets (Kumarasamy, n.d.).

Responsibility for SWM in Lebanon rested with the municipalities, which were tasked with the collection, transportation, sorting, and disposal of waste within their respective areas (Abbas et al., 2017). Unfortunately, many municipalities lack the resources and expertise to effectively manage recycled waste and dispose of landfill waste in an acceptable manner. The government, in turn, faced financial challenges in funding waste management services, leading to a situation where many municipalities could not afford the services they needed. Consequently, municipalities were grappling with several challenges (Abbas et al., 2017), including insufficient assistance in technical matters, financial limitations, difficulties in identifying suitable locations for landfills, and encountering strong opposition from neighboring communities (Abbas et al., 2017). The situation has become so dire that some communities have taken matters into their own hands. In some areas, residents have started to collect and sort their waste and set up their own composting facilities.

This thesis centers on examining the environmental impact of landfills in Lebanon and exploring their broader implications for social and economic aspects. A notable research gap exists regarding the efficacy of current waste management practices in the country and the potential for sustainable alternatives to landfills. The study aims to highlight key challenges in Lebanon's waste management and offer recommendations to mitigate these issues, seeking to decrease the country's dependence on landfills that are nearing their capacity limits.

The primary issue stems from landfills becoming overloaded with more waste than their original design intended, leading to increased height that can compromise slope stability. This problem is further exacerbated by insufficient compaction efforts and the neglect of slope restoration, resulting in erosion. Urgent attention is required to address this waste problem, minimize landfill usage, and prevent incidents similar to the 2017 landslide in Ethiopia, which resulted in significant

casualties and injuries (France-Presse, 2017). While the ultimate objective is to achieve zero waste production in Lebanon, further research is imperative to assess the feasibility and effectiveness of alternative SWM approaches.

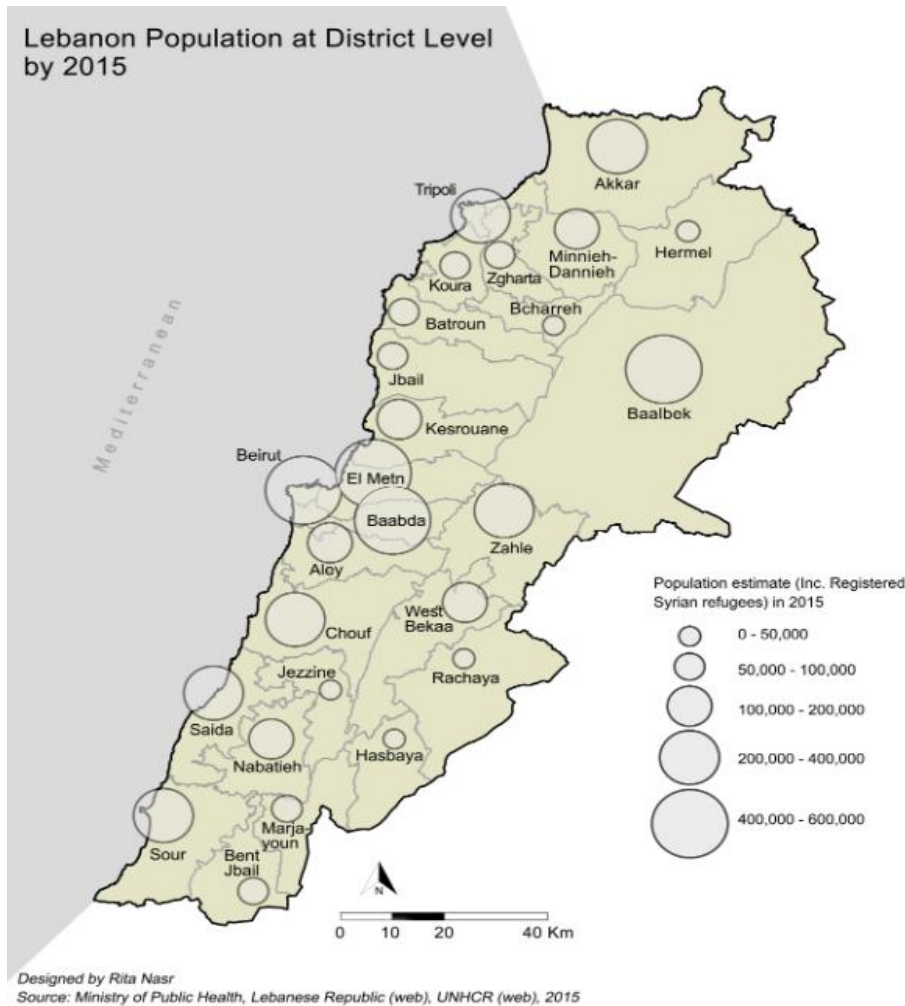


Figure 1: The distribution of the Lebanese population across the country's provinces (Farah, 2020)

1.2 Research Objectives

This research is fundamentally motivated by the urgency to confront Lebanon's significant environmental predicament characterized by escalating waste generation and a conspicuous absence of proactive measures. The primary goal of this study is to systematically examine the

overarching challenges encountered by various entities engaged in waste management, including private enterprises, public institutions, and non-governmental organizations (NGOs). A pivotal objective is to dissect the intricate complexities inherent in waste management, identifying sector-specific challenges such as funding constraints, logistical intricacies, and the inadequacy of policy support. This comprehensive understanding is paramount for formulating precise and effective waste management strategies. Another critical objective is the in-depth investigation of the environmental repercussions stemming from landfills. This entails a thorough exploration of their impact on surface and groundwater quality, air and soil composition, noise pollution, and windblown litter. Beyond environmental considerations, the study rigorously scrutinizes the socio-economic ramifications associated with landfill activities, focusing on public health issues, community displacement, and broader implications for economic vitality. The ultimate aim is to contribute actionable recommendations that emphasize timely intervention, information sharing, policy alteration, financial incentives, and the implementation of a cost recovery mechanism. By accomplishing these objectives, the research strives to provide pragmatic and implementable solutions, ultimately contributing to a foundational understanding of Lebanon's waste management landscape.

1.3 Research Question and Sub-questions

Based on the above, the following research question has been formulated:

" What are the key challenges hindering the efficient implementation of a sustainable waste management plan designed to reduce solid waste in landfills and mitigate associated environmental and socio-economic consequences? "

Additionally, to answer this research question properly, the following sub-questions have been formulated:

- *How does the presence of landfills impact the natural environment, specifically surface and groundwater sources, as well as air and soil quality, noise pollution, and windblown litter?*
- *What socio-economic consequences arise from the presence of landfills in the surrounding areas?*
- *What are the primary challenges encountered by both the public and private sectors, as well as individual initiatives, in the implementation of waste management practices, and how do these challenges impact the effectiveness of waste management systems?*
- *What strategies can be implemented to encourage the adoption of waste management practices at the individual level?*
- *How can systemic-level strategies be devised and implemented to promote the widespread adoption of effective waste management practices?*

1.4 Research Relevance

1.4.1 Scientific Relevance

The scientific relevance of this thesis is paramount as it centers on addressing the urgent environmental challenges currently confronting Lebanon. The ongoing waste management practices in the country have given rise to a range of detrimental effects, notably causing water, land, and air pollution, with severe health implications for communities residing in close proximity to landfills. The research outlined in this study brings attention to these challenges, aiming to underscore the importance of adopting practices that not only manage solid waste but also proactively work towards reducing waste volume by mitigating the discussed challenges.

By highlighting the challenges inherent in the current waste management operations, the study seeks to support the development of practices that transcend conventional approaches, striving to establish a system that not only mitigates environmental harm but actively reduces waste

generation. The scientific relevance of this research lies in its potential to guide Lebanon's transition from an inefficient and almost non-existent waste management system to one that aligns with sustainability principles, ultimately working towards the realization of a zero-waste society.

1.4.2 Societal Relevance

Another aspect to consider about this thesis is its examination of the societal relevance of waste management in Lebanon. The managing of municipal solid waste (MSW) is indeed an environmental hardship in Lebanon – and a social one as well. A significant aspect of this thesis is to raise awareness and educate people about the importance of recycling and reusing waste. There is an urgent need for an enhancement in the quality and standard of life of Lebanese citizens, as well as public health. In order to also achieve economic growth and development, a sustainable waste management plan should be implemented.

Effective waste management practices are crucial for achieving the Sustainable Development Goals (SDGs) set by the United Nation (UN) during the Paris Agreement (Figure 2), especially SDGs 6 (clean water and sanitation), SDG 11 (sustainable cities and communities), SDG 12 (Responsible Consumption and Production) and SDG 13 (Climate Action). It is possible to slow down climate change by reevaluating the resources used. Prioritizing waste reduction through strategies like reuse, recycling, and repair is the best method to accomplish this. By doing this, we may lessen emissions brought on by the production and disposal of goods. According to Hub (n.d.), recycling aluminum cans saves 96% more energy than producing them from scratch. Recycling may result in considerable energy savings, which is in line with SDG 13's goals and promotes a more sustainable method of production and consumption.



Figure 2: *United Nations' 2015 SDGs (FUND, 2015)*

Furthermore, such a function strategy can add to improving the living conditions of the Lebanese by offering a healthier lifestyle. The government should foster better life and well-being conditions for the citizens by launching a well-founded waste management policy.

The current societal and academic knowledge gap that this research aims to address revolves around the challenges and shortcomings in Lebanon's waste management practices. While the environmental hardships resulting from inadequate waste management are evident, there is a gap in comprehensive understanding and strategic solutions that encompass ecological, economic, and social dimensions. The research seeks to bridge this gap by systematically examining the specific challenges faced by various sectors, including private, public, and NGOs, in the implementation of sustainable waste management practices.

In essence, this research addresses the current knowledge gap by offering a holistic examination of Lebanon's waste management landscape, providing actionable insights for practitioners, policymakers, and researchers to develop sustainable and effective waste management strategies.

1.5 Expected results

This thesis aims to systematically investigate the challenges confronting various sectors within the domain of waste management. The objective is to provide informed recommendations for enhancing the waste management sector in Lebanon and mitigating the reliance on landfills.

The research centers on an exploration of the environmental repercussions of landfills, encompassing their impact on sea-level and groundwater levels. Additionally, it delves into the social implications experienced by individuals residing in close proximity to these waste disposal sites. The anticipated outcomes of this research serve as a catalyst for encouraging both Lebanese citizens and the government to curtail the generation of specific types of waste. Furthermore, it advocates for improved waste handling practices, thereby contributing to the safeguarding of access to clean water and fostering a healthier lifestyle.

In summation, the findings are poised to empower the Lebanese government and its citizens by shedding light on the detriments associated with illegal and overburdened landfills. The envisaged sustainable waste management plan holds the potential to bring about positive transformations in Lebanon's environmental, economic, and social landscape. Through its implementation, not only would the nation witness advancements in its overall conditions, but it would also fortify the well-being of its residents.

1.6 Thesis Structure

Moving to the thesis structure, this thesis is of a structured approach (Table 1). To begin with, the 1st Chapter: The Introduction, will offer a comprehensive background on the study. This chapter will also tackle the research objectives, research questions, and sub-questions where they will be outlined in order to establish the context for the entire study. In addition to that, this 1st chapter will also present the relevance of the research in two aspects: existing knowledge and practice. Moving to the 2nd chapter: Literature Review, will be conducted in order to offer a closer look into the effects of landfills. It will explore how landfills assist in pollution and also have severe socio-economic and environmental disadvantages. Furthermore, it will also dive into how waste is being managed in Lebanon. As for the 3rd, it will be dedicated to the research methodology which specifically tackles the research strategy and methods employed, such as desk/secondary research and semi-structured interviews. The 4th chapter will expound on the findings of this study, which will cover the present-day situation of waste management in Lebanon and its challenges. Then, it will be analyzing the interviews. Finally, the 5th and 6th Chapters will present the study's insights, discussion recommendations, and conclusions based on the results of the research.

Table 1: *Chapter's Structure Overview*

<i>Chapter</i>	<i>Overview</i>
<i>First Chapter</i>	Tackle the research objectives, & questions.
<i>Second Chapter</i>	Explores disadvantages of landfills.
<i>Third Chapter</i>	Dedicated to the research methodology.
<i>Fourth Chapter</i>	Expound on the findings of this study and analyze it.
<i>Fifth Chapter</i>	Presents the discussion and recommendations.
<i>Sixth Chapter</i>	Present the conclusion of the thesis.

Chapter Two: Literature Review

2.1 Municipal Solid Waste

MSW stands out as the most significant type of waste that poses a severe risk to the environment and contributes to various forms of pollution and greenhouse gas (GHG) emissions (Bhella et al., 2013). In addition to the environmental impact of landfills, MSW contains hazardous substances, including heavy metals and organic compounds, coming from household products and pharmaceuticals, contaminating both the soil and water sources, and posing threats to human health and marine life.

EEA (2013) defines MSW as solid waste that is created within a municipality or urban region by homes, business organizations, institutions, and small industries. Yet, because of variations in waste creation trends, management strategies, and legislation, the definition and content of MSW vary by country (EEA, 2013). Eurostat (2018) states that in some countries, MSW may contain construction and demolition waste. Waste created by households' accounts for the majority of MSW, although it also includes waste from offices, enterprises, government facilities, and bulky waste. On those same lines, Zhao (2009) classifies MSW based on its sources, such as home garbage, industrial waste, and waste from commercial service locations.

Despite this, managing MSW faces numerous challenges at different stages (Mohamad, 2012). The collaboration between municipal and federal governments significantly influences municipal solid waste management (MSWM) and control. However, Klundert (1999) argues that directly connected arrangements may not suit waste management in developing nations, primarily due to the preference of foreign donor countries for costly equipment. Political interference hinders the effective implementation of sustainable waste management strategies. Ramos et al. (2012) highlight major economic constraints in waste management, such as a lack of financial support

from the government, expensive initial setup costs, and high capital and operational expenses. Furthermore, conflicts at the local level emerge between proponents and opponents of incineration due to concerns about public health and the environment (Rootes, 2009).

2.1 Impact of Landfills

2.1.1 Landfills Gas

Due to its reasonably low cost, waste disposal by landfill has historically been the preferred method for waste disposal. However, they actually emit hazardous gas into their surrounding air, and if not supervised, landfill gas creates air pollution and contributes significantly to GHGs (Klusman and Dick, 2000). In order to steer clear of any drastic effects on the environment, it is essential to take action to manage landfill gas. An important note here is that the quantity of gas emitted from landfills is based on the composition of the waste, its age, the temperature, and compaction effort (Marković & Stevović, 2016).

Due to waste accumulation in landfills, and due to the pressure increase in the center of these sites that comes with that, landfill gas is released into the surrounding environment. Joshi & Pant (2018) explain that this gas is a complex mixture that consists of many different gases – with methane and carbon dioxide being the most prevalent, accounting usually for around 45-60% of methane and around 40-60% of carbon dioxide. It is noteworthy to mention that methane is up to 20 times more harmful than carbon dioxide in terms of its impact on the environment. While these gases are the most prevalent, other gases such as nitrogen, oxygen, ammonia, sulfides, hydrogen, carbon monoxide, and Non-Methane Organic Compounds (NMOCs) such as trichloroethylene, benzene, and vinyl chloride, are present yet in lower concentrations (Joshi & Pant, 2018).

Landfill gas emissions result from a complex interplay of various reactions, encompassing chemical, bacterial, and volatilization processes. Among these, bacterial decomposition, occurring

predominantly in the five-layer waste and soil covering landfills, is the most prevalent (Anon, 2019). Throughout each stage of these five phases, there are alterations in the composition of gases (Anon, 2019).

Simultaneously, volatilization becomes a potential occurrence during the transformation of organic matter from a solid or liquid state into a gas (Joshi & Pant, 2018). This transformation may contribute to the production of NMOCs in landfill gas (Anon, 2019). Additionally, there exists the possibility of landfill gas formation through the reaction of specific compounds within the waste (Anon, 2019). The intricate nature of these processes underscores the multifaceted origin and composition of landfill gas emissions.

Several factors affect the quantity of landfill gas emitted by bacterial decomposition, such as the amount of organic waste in the landfill (Marković & Stevović, 2016). The existence of what is called “nutrient-rich organic waste” – contains salt, potassium, calcium, and magnesium – promotes the growth of bacteria and aids in increasing gas production (Marković & Stevović, 2016). In contrast, some waste might also contain substances that inhibit bacterial growth, which would result in less gas production (Marković & Stevović, 2016). For example, new landfills rely on gas collection systems that trap produced methane, and other gases, during decomposition (Amini et al., 2013). This gas collected would be later used as a source of energy or sold to other industries, further leading to a reduction in GHG emissions while also generating revenue for the landfill (US EPA, n.d.). In addition to that, gas collection systems aid in preventing underground explosions or fires, which can be created or initiated when methane levels increase and reach explosive levels (ATSDR, 2019). Yet, if methane, is not sold or used as an energy resource, it can be flared off to prevent gasses from being released into the atmosphere.

2.1.2 Landfills Leachate

Wiszniowski et al. (2006) identify leachate as a liquid waste that is created by the decomposition of other waste, and supplemented by infiltrated rainfall. On those same lines, landfill leachate is formed as a result of the biological, chemical, and physical reactions water undergoes when it percolates through the layers of waste (Colombo et al., 2019; Andréia et al., 2018). In developing countries, the lack of proper SW disposal in landfills threatens the quality of groundwater and surface water, and this threat mainly stems from the probable leakage of leachate through broken landfill liners (Mishra et al., 2018). These liners typically consist of impermeable materials like geomembranes, clay, plastic, or synthetic clay, placed beneath the landfill to prevent the ingress of leachate into groundwater sources. Additionally, a final cover is placed above the landfill to prevent rainfall infiltration. The more the levels of precipitation increase, the more the levels of leachate in landfills increase, especially during wet seasons (Chiang et al., 1995). This issue is exacerbated when the waste, especially highly organic material undergoing decomposition, is particularly moist. This is generally referred to as wet waste.

Taylor and Allen (2006) illustrate that waste-derived liquids are the most common cause of groundwater pollution from landfills. Yet, all locations that contain concentrated, processed, or stored – even for a short time – waste, have the potential to contaminate groundwater (Oyiboka, 2014). Leachate emitted from landfills poses a huge threat to groundwater if not appropriately managed (Ikem et al., 2002). Lee and Jones (1991) found that around 75% of an estimated 75,000 landfills, pollute near groundwater with Leachate. Mohammed et al. (2009) argue that to improve the handling of groundwater pollution, we must acknowledge the rate of chemical release along with the leaching of nutrients and metals through macropores, as well as acknowledge the effects of organic substances on the degeneration process. Waste in soil may contain toxic substances that can contaminate both groundwater and surface water. The contamination arises from the release of methane, carbon dioxide, and leachate emissions (Ikem et al., 2002). Additionally, the unsaturated zone, attenuation capacity of the site, and total and effective precipitation may also pollute groundwater (Ikem et al., 2002).

Ghafoori (2021) suggests that improper disposal of landfills, which inevitably emit leachate, leads to significant environmental issues, thus there is an urgent need to treat leachate properly. To avoid excessive volumes of leachate, planning, construction, and management of landfills should be done by experts (Muralikrishna, 2017). One method to tackle the leachate involves the implementation of a network of perforated pipes, focusing on the proactive collection of leachate within the landfill. These perforated pipes are strategically placed to capture leachate as it is generated, directing it toward treatment facilities for subsequent processing. This method is primarily concerned with the efficient containment and management of leachate at its source within the landfill, aiming to prevent environmental contamination and ensure proper treatment.

On the other hand, air stripping, as suggested by Renou (2008), is a specific treatment method for leachate. It involves the removal of volatile compounds, particularly ammonium nitrogen, from the leachate. The process utilizes air to strip off these volatile components, leaving behind a treated effluent with reduced concentrations of harmful substances. Air stripping is an essential step in the treatment of leachate, specifically targeting the removal of specific contaminants to meet environmental standards.

Milad (2014) explained that both the waste type and the degree of waste biodegradation are what determine the composition and level of contamination in leachate. For example, if the origin of the leachate is biodegradable waste, there is a probability it will hold significant amounts of natural substances that are harmful to living organisms (Renou et al., 2008). Also, leachate contains organic matter, volatile fatty acids, refractory compounds, and xenobiotic organic compounds (Kjeldsen et al., 2002), all of which can lead to acute, chronic, and genotoxic impacts on multiple organisms when discharged into marine environments (Mukherjee et al., 2015).

The composition and pollution intensity of leachate in landfills are influenced by various factors, including the age of the landfill, its hydraulic conditions, and the waste ingredients, as highlighted by Bidhendi et al. (2010). Furthermore, it was reported by Longe and Balogyn (2010) that the following factors determine the rate and characteristics of leachate production: SW composition, cover design, compaction, the interaction of leachate with the environment, and landfill design operation, degree of compaction, hydrology, and hydrogeology of site, age of landfill, moisture and temperature condition, and available oxygen.

Nevertheless, many modern landfills include a special leachate collection system located above the bottom liner in order to stop leachate contamination of earth and groundwater (Figure 3). Nathanson (2022) adds that the collection system includes a network of pipes to gather the leachate. After leachate is collected it still needs management and that's where Fickes (2011) highlights three common ways of managing leachate. The ways of treating leachate include re-circulating where leachate is sent back to the landfill to speed up the process, in addition to treating the leachate on-site and then discharging it to a close stream with the necessary legal permits, or partially treating the leachate so that it matches the local wastewater treatment plant standards before treating it (Fickes, 2011).

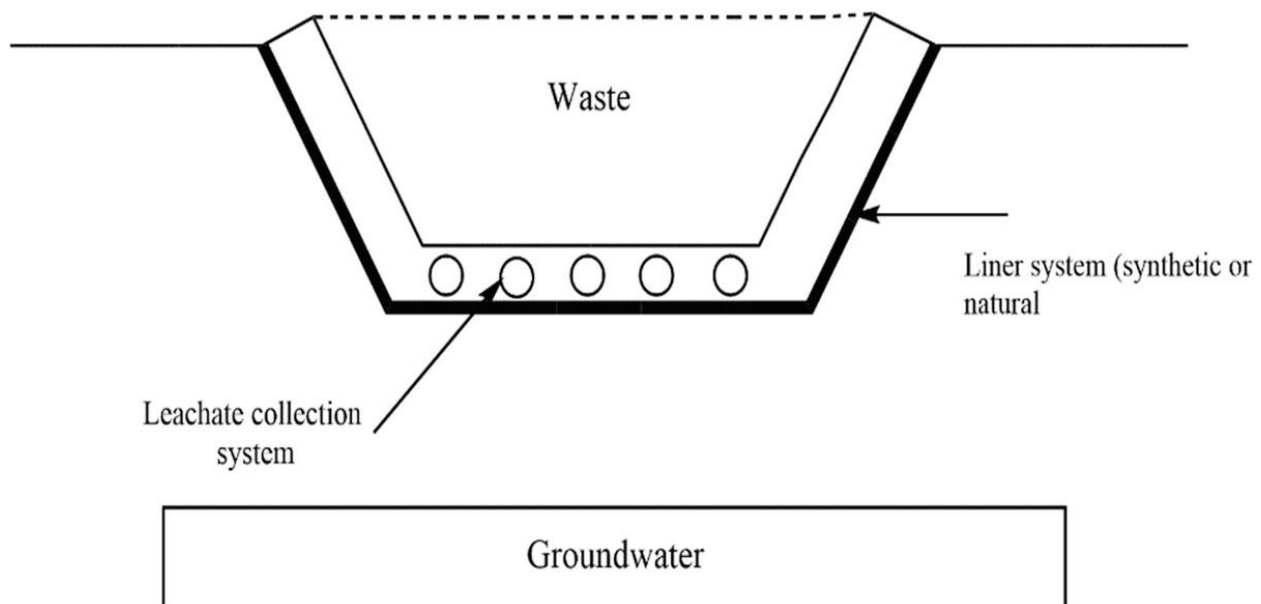


Figure 3: *Leachate collection system (Khasawneh et al. 2022)*

2.1.3 Landfill Stability and Landslides

Landfills eventually lead to landslides and other dangerous impacts if landfills and the waste disposal in it are not managed the proper way. Landfill stability has become a consistent hardship

throughout the years due to the complexity of waste composition and the lack of knowledge about the principles of waste management (Xiu, 2021). Over the last twenty years, countless devastating incidents led to landfill landslides all over the world, examples of that are the Bandung dumpsite in Indonesia and the Payatas landfill in the Philippines (Jahanfar, 2014). These incidents show the need for more extensive studies and evaluations of landfill stability so that loss of human lives and substantial environmental, operational, and economic impacts are prevented (Jahanfar, 2014).

Some landslides are indeed caused by nature, however, landfill landslides are human-made and pose a dangerous threat to neighboring residencies. Once waste accumulates and a landfill reaches its full capacity, its stability declines and thus creates a risk to the people living nearby (Xiu, 2021). So, making sure that landfills are as stable as possible is a matter of importance in the design and operation of these sites, and maintaining stability has been a never-ending challenge for many years (Koelsch, 2007).

Rotaru et al. (2007) identify three main variables as probable causes behind landfill landslides: slope gradient, garbage compaction, and water pressure. Rotaru et al. (2007) also mentions that slope-inclined landfills are most vulnerable to collapse. The lack of systematic waste compaction can lessen the shear strength of waste where it enables water infiltration, leading to increased pore water pressures and decreased cohesive waste (Koelsch et al., 2005). Furthermore, high pore water pressure can weaken waste shear and cause slope collapses (Merry et al., 2005). For instance, leachate emissions and severe rainfall have caused slope collapses and increased pore water pressure (Merry et al., 2005).

2.1.4 Landfill Fires

Due to the increasing frequency and severity of landfill fires globally, they are a concerning issue. Similar to this, Vaverkova et al. (2020) highlighted the fact that the severity of these fires is

increasing yearly, emphasizing how urgent the matter is. These fires are brought on by a variety of chemicals and materials that might catch fire in landfills, such as oil, gasoline, rusted metal, and batteries. These materials are all very combustible and can catch fire spontaneously or as a consequence of outside factors (Esa et al., 2017). There is also a chance that methane and insufficient compaction in landfills are to blame for the high number of fires (US Fire Administration, 2002). A combustible atmosphere is created when methane emissions and inadequate compaction mix. The risk would also rise since the dump would include a lot of flammable materials, especially in dry and hot weather. This sort of fire, once it's started, may be very difficult to put out and, on rare occasions, may continue for days or even weeks, releasing hazardous chemicals into the air and soil (Esa et al. 2017). It's crucial to understand that if a landfill fire breaks out, a significant amount of waste would be reduced to ash causing considerable volume reduction. The sinking and dissolving of debris would decrease the landfill's structural stability, which would then cause the surface to subsidence failure. Large fires that start within landfills represent a serious threat to both the environment and the public's health, according to a study done by Masalegooyan et al. (2022). Vaverková (2019) looked at the environmental dangers posed by toxic gas discharges that contain dangerous substances including dioxins and polynuclear aromatic hydrocarbons in addition to the concerns connected with landfill fires. Long after the fire has been put out, the toxic compounds may still be present in the air, posing serious and long-term dangers to our ecology (Vaverková,2019). Municipal and hazardous waste must therefore be disposed of properly and at the correct compaction ratio to avoid these fires and their unfavorable effects.

Aside from the health consequences that follow the release of toxic smoke, landfill fires have long-term impacts on nature and near residencies (Masalegooyan et al., 2022). Dioxins, furans, heavy metals, and volatile organic compounds are all toxins released from landfill fires that would cause

respiratory problems and other health issues, especially for vulnerable populations like children and the elderly (Aderemi and Otitolaju, 2012). Besides that, fires can cause the structure of the landfill to become weaker, which means that the risk of landslides or collapse incidents would increase, and that would cause physical harm to people and damage property (Jahanfar et al., 2017). Additionally, waste materials in landfills are prone to lose their stability when they might move leading to them contaminating the surrounding soil and water (Koda et al., 2018). This contaminated soil and water can then be carried away by water and migrate to nearby waters, also again: posing a threat to the environment and human health (Abiriga et al., 2020).

Furthermore, if landfill waste ignites and comes into contact with soil lacking a protective covering, it has the potential to cause both physical and chemical degradation of the soil. This, in turn, can exacerbate the instability of the landfill, as highlighted by Koda et al. (2018). This poses a great risk to nearby neighborhoods where people residing there are subjected to high exposure to hazardous waste materials (Jahanfar et al., 2017). Therefore, it is of high importance to take preventive measures and have forethought emergency response plans so that landfill fires are manageable, and their harmful effects on the environment and public health can be reduced.

2.1.5 Socio-Economic Impact of Landfill

Landfills, beyond their environmental impact, give rise to socio-economic challenges. These issues encompass public health concerns arising from exposure to landfill gas and the consumption of water contaminated by landfill leachate. Lioy (1990) elucidated that individuals may encounter contaminants and emissions through direct contact, inhalation, or ingestion, despite modern landfill designs aiming to minimize emissions. Consequently, individuals residing or working near landfills are exposed to toxins (Berry & Bove, 1997).

Studies demonstrate that the ingestion of contaminated water constitutes a significant avenue for exposure to harmful substances, posing health risks (Adami et al., 2001). Exposure to landfill emissions has been associated with adverse health outcomes, including congenital malformations, low birth weight, premature birth, impaired child growth, and various cancers (Danthurebandara et al., 2012). Notably, children born to families within one mile of hazardous waste sites exhibit a 12% higher risk of congenital malformations (Geschwind et al., 1992). Furthermore, populations residing near landfill sites face elevated risks of birth defects and cancers (Dolk et al., 1998).

The establishment of landfills in proximity to residences can result in the displacement of people, particularly in low-income and marginalized communities. This displacement may occur either due to the creation of landfills first or as a consequence of urbanization encroaching on residential areas (Yang et al., 2018). This social dislocation leads to the loss of cultural heritage, traditional practices, and a subsequent sense of disconnection and identity loss in affected societies (Anguelovski et al., 2016).

Economically, landfills are strategically located near residential areas due to the impracticality of placing them far from service areas. This proximity amplifies both social and environmental risks. The costs associated with transporting large volumes of waste make locating landfills near waste sources economically advantageous, mitigating transportation expenses (Dolui & Sarkar, 2021).

The placement of landfills can also generate conflicts between environmental activists and governments, as their priorities and values may diverge. Minority groups and low-income families bear a disproportionate burden compared to other communities, as landfills and hazardous waste facilities tend to be situated in their vicinity (Vasarhelyi, 2021). These vulnerable communities often lack the resources and political influence to oppose landfill placement, stemming from

historical and systemic discrimination, limited access to education, and financial constraints (Ferronato & Torretta, 2019).

Nevertheless, the detrimental impact of landfills extends beyond environmental and health concerns to affect the social fabric of societies. Ulfik & Nowak (2014) elucidate how the construction and operation of landfills introduce disruptive elements such as noise, traffic, and other nuisances, significantly impacting the daily lives of nearby residents. Moreover, the odors emanating from organic waste decomposition and combustion in landfills, along with limited visibility due to aerosol particles and photochemical smog, adversely affect both the psychological and physical well-being of individuals (Sironi et al., 2005; Heicklen, 1976; Singh et al., 2017).

These environmental disruptions can contribute to social tension, conflicts, and potential legal disputes between landfill operators and nearby residents. Kedzierski et al. (2020) elaborate on how tourism suffers as a consequence, with tourists avoiding areas associated with poor environmental and health conditions. Additionally, landfills negatively impact economic activity and job opportunities, as regions with landfills become less attractive to potential residents. This negative perception, in turn, hampers current economic growth and long-term prospects.

The presence of landfills also influences the character of neighborhoods, impacting the balance between industrial and non-industrial activities, the types of homes and businesses in the area, and the demographics of the residents (National Research Council, 2000). Over time, those with the means to relocate may choose to move away from affected areas, leading to changes in ethnic diversity and age distribution within the neighborhood (National Research Council, 2000).

It is crucial to add that the presence of nearby landfills significantly influences land value, land degradation, and land availability. Reichert et al. (1992) observe that the proximity of residences to landfills has an adverse impact on their value, with a diminishing effect depending on the

distance from the landfill. This relationship is explored through the concept of "hedonic regression," which entails analyzing how changes in the environment, such as living close to a landfill, can influence the prices or values of homes. Reichert (1992) underscores the importance of considering hedonic regression and landfill distance as factors in studying house values. Such studies consistently reveal a significant and positive correlation between proximity to landfills and property values. Danthurebandara et al. (2012) support this observation, noting that the presence of landfill-associated toxins, including flies, odor, litter, smoke, noise, and polluted water supplies, deters individuals from residing near landfills.

Beyond the direct impact on property values, landfills generate indirect economic consequences in the surrounding area. A decrease in property values, as highlighted by the National Research Council (2000), leads to reduced property tax revenues. This reduction in revenue, in turn, affects the funding required for local services such as schools and infrastructure projects. Moreover, the decline in property values can result in diminished investment in the area, negatively impacting local businesses. The interconnectedness of these economic factors underscores the far-reaching consequences of landfill presence on both residential and broader economic landscapes.

2.1.6 Landfill's Impact on the Mediterranean Sea

The siting of landfills in proximity to water bodies, such as the Mediterranean Sea, can result in substantial environmental repercussions. The Mediterranean, being of significant ecological and economic importance, serves as a habitat for diverse marine species and supports industries such as fishing, shipping, and tourism (Sumaila et al., 2021). However, the coexistence of landfills near the sea introduces environmental challenges, including pollution, erosion, and climate change (O'Shea et al., 2018).

Tidal movements exacerbate the impact of landfills on marine environments, as seawater infiltrates into landfills situated near the sea (Septiariva, 2021). During rising tides, seawater permeates landfills through openings or cracks in the liner or cover. This infiltration prompts an increase in leachate production, where water entering the landfills modifies biogeochemical conditions (Brand et al., 2018). The ingress of water into landfills induces alterations in moisture levels, chemical composition, nutrient availability, pH, and microbial dynamics within the waste materials. These changes in biogeochemical conditions ultimately contribute to an elevated production of leachate as a byproduct of the waste degradation processes.

Marine pollution is also one of the most important impacts of landfills on the Mediterranean Sea. Landfills are a source of a wide range of pollutants and toxins, including heavy metals, organic chemicals, and plastics (Reinhart, 1993). Waste disposal in landfills discharges pollutants into nearby water sources, including rivers and groundwater (Siddiqua et al., 2022), eventually making their way into the Mediterranean Sea. This significantly harms marine life, including fish, mammals, and birds, as well as damages the ecosystem and marine food chain (Limoli et al., 2019). Plastic waste has accumulated in the ocean and that is very alarming because it forms microplastics that are ingested by marine life and can have long-term health effects (Sharma & Chatterjee, 2017). In addition to the deleterious effects on aquatic ecosystems, landfills contribute to coastal erosion and the degradation of marine habitats (Stringfellow et al., 2021; Nicholls et al., 2021). The principal driver behind this erosion is the impact of climate change induced by landfills (Wilby & Perry, 2006). Lelieveld (2012) asserts that landfills have the potential to influence climate change, leading to rising sea levels and an increased frequency of extreme weather events. The consequences of these changes extend to coastal areas, exacerbating erosion and habitat destruction.

The establishment of landfills necessitates extensive land clearing, resulting in the destruction of natural habitats and alterations to the area's natural topography. This widespread habitat disturbance significantly contributes to coastal erosion and the loss of biodiversity (Aluko & Sridhar, 2005). The disruption of natural ecosystems and topographical changes induced by landfill development can intensify the vulnerability of coastal regions, exacerbating the impact on both terrestrial and marine environments. The interconnectedness of landfills, climate change, and coastal dynamics underscores the intricate web of environmental consequences associated with improper waste disposal practices. Sustainable waste management strategies are imperative not only for mitigating aquatic pollution but also for safeguarding coastal ecosystems from the far-reaching effects of landfill-induced climate change and habitat disruption.

Figures 4 illustrate the position of the Bourj Hammoud landfill in close proximity to the Mediterranean Sea. This geographical configuration poses challenges for conducting an impact assessment, potentially leading to significant risks for the surrounding environment and marine life.



Figure 4: *The overview of Bourj Hammoud's landfill in the Mediterranean Sea. (Beato, 2023)*

2.2 Waste Management

2.2.1 Circular Economy

Andersen (2007) described the term "circular economy," and it focuses on four economic functions of the environment – the provision of amenity values, a resource base for the economy, a sink for waste flows, and a system for life support – that are all interconnected. As per CIRAIG (2015), the main goals behind the circular economy are to minimize the misuse of resources, such as energy and raw materials, to detach resource usage from the growth of gross domestic product, to reduce ecological effects, and to enhance human wellbeing, including increasing employment opportunities. A circular economy aims to decrease waste by recycling resources whenever feasible, in contrast to the traditional linear economy, which typically ignores the societal cost of waste (ING, 2017). The concept of the circular economy involves three main actions: reducing, reusing, and recycling, and these actions are applied through every single cycle of products and

services, starting from the production stage to consumption and along with them to reach their circulation (Jiao and Boons, 2014). However, the new recycling hierarchy expands those three main actions to have 4 stages before the step of recycling (Johnson, 2013). According to Balawan (2022), the 5 stages (5R) serve as principles to lead an eco-friendlier and sustainable lifestyle (Figure 5). Balawan (2022) explained that the first step, Reuse, encourages us to reject unnecessary items like single-use plastics and non-recyclable products. Reduce follows, urging the reduction of wasteful materials, and conserving resources such as energy and water. Renew involves giving new life to waste materials, and saving money and energy by repurposing items before discarding or recycling them. Repurpose encourages creative upcycling, finding new uses for items initially intended for something else. Finally, Recycling converts waste and used materials into reusable products, reducing pollution, energy consumption, and the need for new raw materials.

Regarding circular economy, Andersen (2007) highlights that not only does it reduce the cost of the production system, but it also does help in reducing environmental pollution by promoting waste recycling. For example, MSW can be turned into a resource in order to generate biogas, such as Methane, that is useable as an alternative fuel source in power generation (Rathore & Sarmah, 2020). This strategy eventually decreases reliance on coal, thus easing the pressure on coal mines, and lastly reducing environmental pollution (2020).



Figure 5: *The “5R” Framework (SunChemical, n.d.)*

MacArthur (2015) puts out three guiding principles for the circular economy: design out waste and pollution, maintain goods, components, and materials at their greatest value and in use, and regenerate natural systems. According to MacArthur (2015), the material flow in a circular economy falls into two main categories: the biological cycle and the technical cycle. In biological cycles, renewable materials are recycled, while in technical cycles, technological materials are typically repaired without affecting the biosphere (Figure 6).

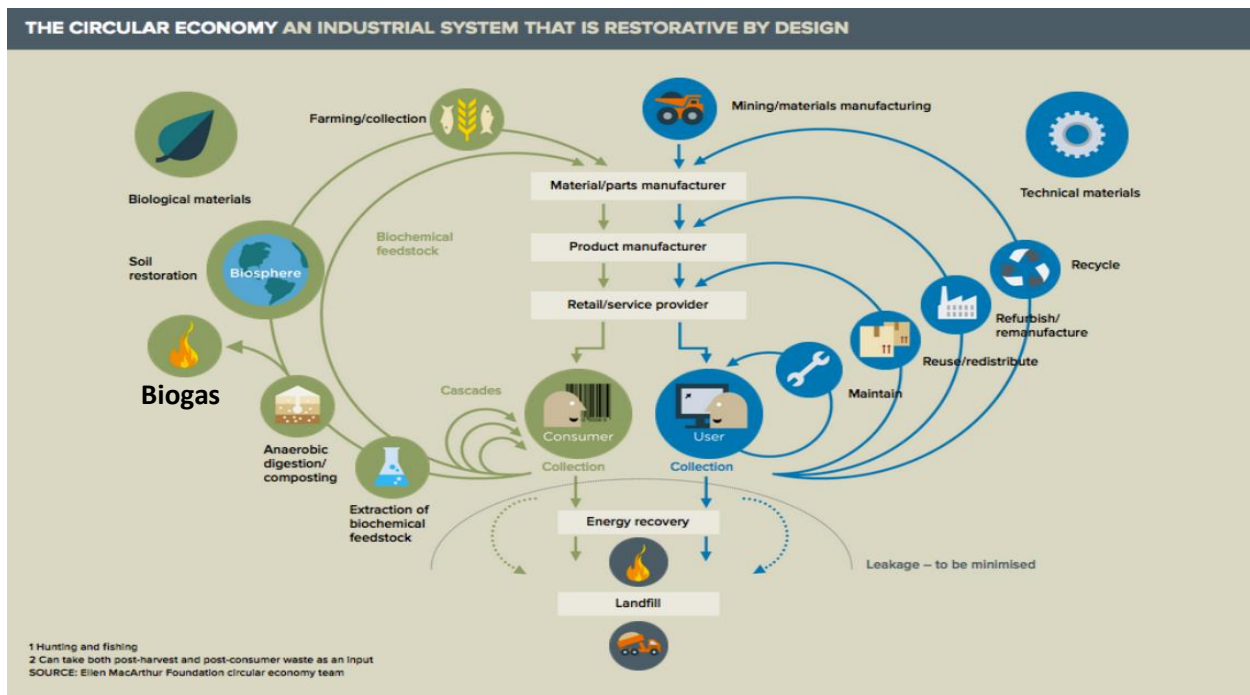


Figure 6: *The Circular Economy diagram from Ellen MacArthur Foundation’s vision (2012)*

Ever since the establishment of the circular economy, this scheme attracted the interest of people globally, especially in China, where it is viewed as a foundation for sustainable growth (Feng, 2004). This type of economy is used as a strategy in countries as it is viewed as an important way of achieving sustainable economic and environmental progress (COM, 2015). According to Zhao (2016), the circular economy tries to promote industrial transformation and employment growth while also trying to reduce resource consumption and promote effective resource usage, all of which contribute in the end to achieving a sustainable waste management strategy. When a circular economy is implemented in waste management plans, it is important to undergo structural adjustments along the whole value chain, such as advancements in corporate and consumer practices in design, technology, financial strategies, and legislative frameworks (COM, 2014).

2.2.2 Solid Waste Management

Waste management is continuously developed and has evolved throughout time in order to provide environmental preservation (Morrissey & Browne, 2004). All aspects of waste management include measures that would reduce waste generation, such as at-source-separation, reusing, and recycling, identifying and managing waste sources, and adopting effective disposal techniques (Morrissey & Browne, 2004). In order to assure natural and urban cleanliness, professionals in charge of waste management must provide garbage collection and transportation (Asnani, 2006). Asnani (2006), states that one of the main aspects that attract people to a certain city is cleanliness. Similarly, waste management has evolved over time to encompass the processing and recycling of waste, in addition to its collection and disposal (Tsai, 2008). Recycling is a key component of waste management, as it helps limit the amount of waste that is disposed of in landfills, thus preserving natural resources and reducing environmental damage (Tsai, 2008).

According to PDAC (2009), recycling is facilitated by categorizing waste and avoiding on-site disposal. Sustainable waste management attempts to use the most possible of energy-intensive raw materials that are becoming more and more limited (PDAC, 2009). This strategy conserves natural resources while minimizing waste at the same time, resulting in a cleaner and healthier environment.

2.2.3 Integrated Sustainable Waste Management

A crucial step regarding how to reduce the harm done by waste to the environment and public health is integrated sustainable waste management. Daskalopoulos et al. (1999) emphasize that this process requires managing the waste materials from production to end-of-life disposal and renewal methods. This means that waste products have to be treated carefully throughout their generation, as well as their appropriate storage, management, and disposal (1999). When waste is

handled sustainably, stopping pollution wouldn't stay unreachable, GHG emissions would be reduced, resources could be saved, a circular economy could be advanced, and a transition to low, or zero-waste societies, would be achieved. Additionally, re-evaluating the production of certain products, such as polystyrene, is important because some disposal challenges are associated with them.

2.2.3.1 Product Re-design and Eco-Friendly Measures:

Taelman (2018) focuses on the importance of re-designing products and processes in order to achieve sustainable waste management, and that is done by optimizing the use, and reuse as well, of waste in order to prevent its impact on the environment. The objective here is to enable those materials to circulate through either man-made or natural systems in cycles, thus maximizing their utility and performance (Taelman, 2018).

In order for sustainable waste management to become achievable, eco-friendly measures – such as waste reduction, in addition to recycling and reusing, both biodegradable and non-biodegradable materials – must be used (Ogunrinola & Omosalewa, 2012; Crown, 2012). The conservation of natural resources, usage of less energy, and GHG emission reduction emissions may all be achievable by recycling and reusing waste materials.

As per Ramachandra and Bachamand (2006), the reason why waste management procedures are to be prioritized is to reduce the harmful effects untreated waste has on the environment and human health. Lansink (1979) considers that the most ideal method of waste management is waste prevention, which is followed by material reuse and recycling. Similarly, the European Commission (2008) considers reusing and recycling as the most ideal method of waste management. Meanwhile, landfilling or disposal is the least favored choice in the waste management hierarchy because it has harmful environmental effects (Zuberi and Ali, 2015).

Nevertheless, recycling every material present in municipal waste may not always be feasible due to logistical, financial, and environmental constraints (Burnley, 2011).

Figure 7 below presents the waste hierarchy diagram, illustrating the prioritization of waste management methods from the most preferred to the least preferred.

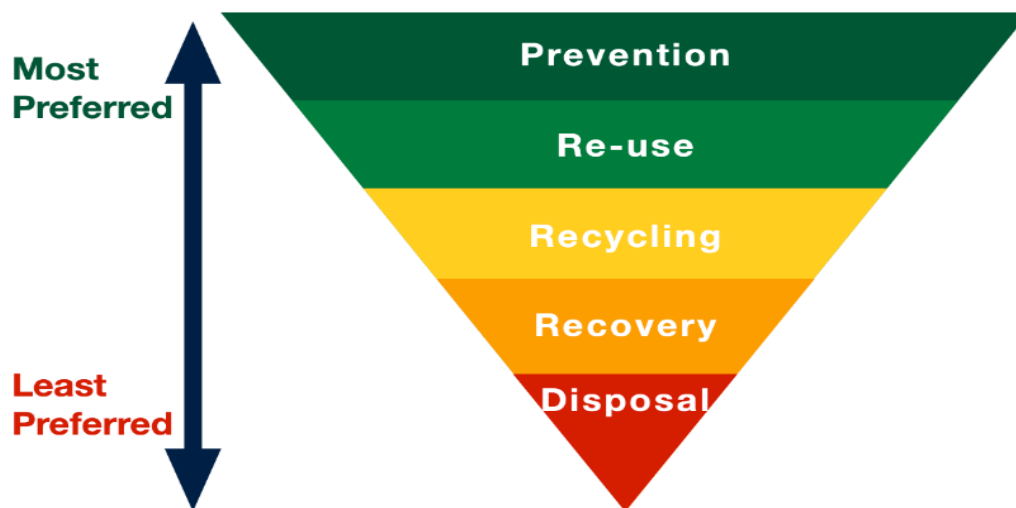


Figure 7: *The waste hierarchy diagram. (ISM, 2021)*

2.2.3.2 Resource Rehabilitation and Household Engagement:

A necessary goal behind a SWM system is resource rehabilitation, which is the retrieval of energy from waste (Zaman, 2014). Resource rehabilitation has been preferable over incineration and landfilling because with it energy is extractable from waste leftovers through energy production facilities (Ramachandra and Bachamand, 2006). Back to the circular economy, this method is very supportive, and it also reduces GHG emissions and protects natural resources. This procedure has the potential to convert landfills into biogas and power producers, eventually producing renewable energy.

Adding to that, household participation in sustainable waste management should be encouraged in order to achieve a more sustainable society (Atthirawong, 2016). To do this, acknowledging the elements that influence household engagement in sustainable waste management is essential. Atthirawong (2016) adds that access to waste management infrastructure, in addition to societal norms, and individual attitudes can all have an influence on household involvement in waste management.

2.2.3.3 Government Strategies and Community Involvement:

Governments also play an important role in creating a successful waste management system, and for them to do so, they need to spread awareness about the harmful effects of improper waste disposal and motivate citizens to participate in resource allocation activities (Kalra, 2020). There are numerous strategies to include communities in the waste management process (Kalra, 2020). Kalra states how individuals can be recommended to separate their house waste at their own homes before being collected (2020). Salvagers can sort the waste at dumping sites to collect what is recyclable, while waste dealers can volunteer with local authorities to assist in waste management (2020). Lastly, community members can intermediate between locals and the authorities, thus they have the ability to give notes on SWM and encourage for reforms (2020).

What's also important in the matter of household engagement in sustainable waste management are individual environmental views. Tilikidou (2007) explains that individuals who have environmentally conscious views are the ones most likely to participate in recycling programs and support initiatives that protect the environment. This brings up the importance of environmental education and awareness-raising in encouraging households to engage in sustainable waste management practices.

One way how people can participate in SWM is through the production of “Ecobricks.” Ecobricks are plastic bottles that are filled with non-biodegradable waste such as plastics, wrappers, and other materials that are not easily recycled or decomposed (Waste-ED., n.d.). One filled ecobricks, are used as building materials for many things such as benches and walls (Figure 8 & 9). Ecobricks are typically created by individuals who want to reduce plastic waste in their community and leave a positive environmental impact.



Figure 9: Ecobricks bottle sample (Alliance, n.d.)



Figure 8: Design for an ecobricks circle planter (Waste-ED., n.d.)

2.2.3.4 Environmental Knowledge and Socio-demographic Factors:

What can also affect pro-environmental behavior is environmental knowledge. Izagirre-Olaizola et al. (2014) claim that people who have decent information about environmental issues and the pros of sustainable waste management practice tend to engage in them more than others. So, sharing information about the environmental effects of outdated waste management practices and

the pros of sustainable waste management with households could encourage greater participation (Laskova, 2007).

Additionally, it's noteworthy to consider how socio-demographic factors, including age, education, and income, play a role in influencing household participation in sustainable waste management. Research by Izagirre-Olaizola et al. (2014) suggests that older individuals may exhibit lower participation rates in recycling programs when compared to those with higher levels of education and income.

Population age significantly influences waste composition, with distinct patterns emerging across various age groups. Younger generations, characterized by a penchant for convenience and on-the-go products, tend to generate a substantial amount of waste, often in the form of disposable packaging and single-use items. The lifestyle choices of youth and young adults, marked by fast food consumption and a preference for trendy consumer goods, contribute to this trend. This demographic's waste stream is often characterized by a prevalence of easily disposable items. In contrast, middle-aged adults typically produce a diverse mix of household waste. This includes packaging from family-sized products, personal care items, and general household goods. The elderly population, characterized by smaller households and potentially more frugal lifestyles, tends to generate less overall waste. However, medical waste, including pharmaceutical packaging, may be more prominent in this demographic due to healthcare needs. The aging population's waste composition may reflect a balance between reduced consumption patterns and an increased need for healthcare-related disposables.

Figure 10 provides insight into the demographic composition of the Lebanese population, showing that the Lebanese community is characterized by a notable absence of elderly individuals.

Which gives the Lebanese community the opportunity to engage more easily and efficiently in the recycling programs.

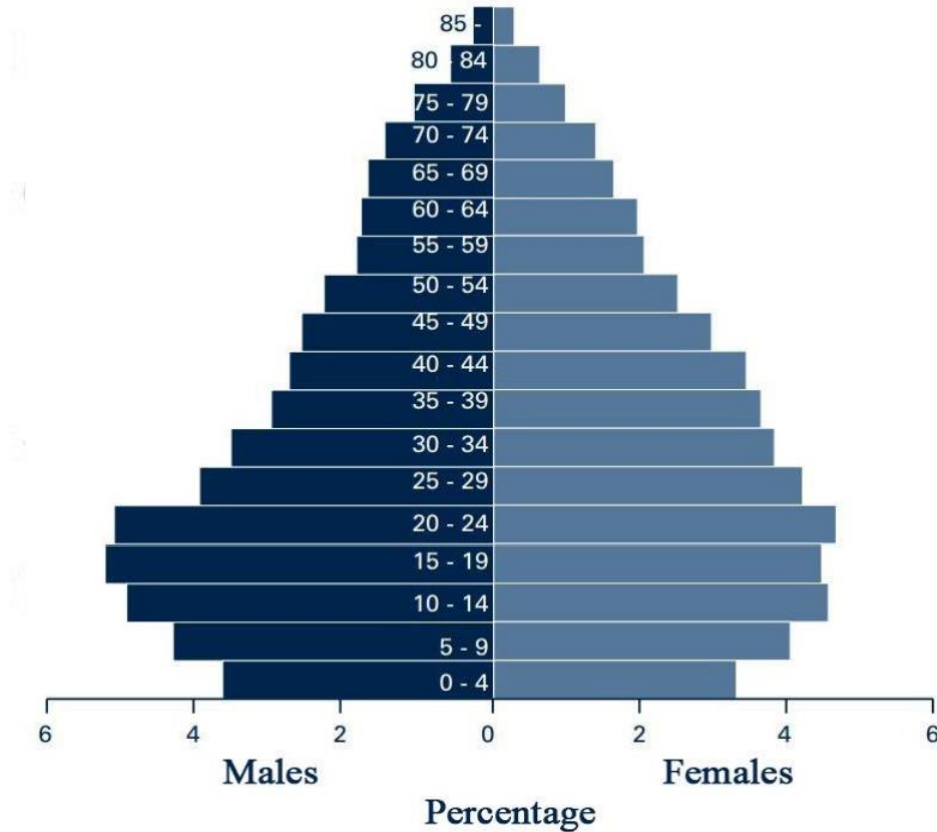


Figure 10: Lebanon's Population Landscape (Maassarani et al, 2021)

2.3 Challenges facing the Lebanese Waste Management Sector

Despite the increase in MSW in Lebanon, there seems to be a lack of community knowledge and participation in waste generation and disposal practices. This led to an expected rise in MSW generation rates from 1.57 Million tons of waste per year to 2.4 million tons per year by 2035 (Sweep-NET, 2014). In Lebanon, around half of the MSW is buried in landfill sites, whereas a third of it is thrown away, and the rest is recycled or composted (Sweep-NET, 2010).

The waste management challenges Lebanon faces have far-reaching consequences, leading people to resort to improper disposal practices in areas not designated for landfills or in landfills unsuitable

for waste dumping. This has, in turn, intensified environmental and visual degradation, creating a complex problem exacerbated by hazardous MSW, including chemicals and medicines, contributing to an annual increase of around 50,000 tons (Halwani et al, 2020). The broader spectrum of waste types, such as those from the food industry and construction, further complicates the already problematic waste management scenario.

As Lebanon grapples with these waste-related issues, the situation is compounded by external factors, such as the Syrian refugee crisis. With over one million Syrian refugees in the country, there is a substantial surge in waste generation, significantly amplifying the demand for waste management services. This surge places an additional burden on already overstretched municipalities, as they strive to meet the increased needs and challenges brought about by the refugee crisis (Blanchet, 2016).

The intricacies of Lebanon's challenges extend beyond waste management, intertwining with the economic landscape. The severe impact of the 2020 economic crisis, characterized by the devaluation of the Lebanese Lira and economic inflation, has created a ripple effect. This economic turmoil has led to a significant rise in the cost of day-to-day activities, pushing many individuals below the poverty line and depriving them of access to basic necessities. In 2021, as reported by the Ministry of Environment (MoE), multiple regions in Lebanon experienced a reduction in waste production. This decrease can be attributed to the fact that people had less waste to dispose of initially due to their limited disposable income.

However, the challenges faced by Lebanon go beyond economic hardship. The political instability in the country, coupled with its economic woes, has had a profound impact on SWM. Currently, Lebanon is struggling with severe inflation, and the volatile price fluctuations can be directly traced back to the devaluation of the Lebanese pound compared to the US dollar, as reported by

the World Bank Group in 2021. The situation was further complicated by a shortage of fuel for garbage trucks and insufficient funding for waste treatment facilities, exacerbating the waste management crisis.

To compound these issues, a catastrophic explosion occurred on the 4th of August, 2020, described to be one of the hugest explosions in the region, taking place in Beirut and causing devastation on various levels. This explosion left behind enormous waste, especially building and demolishing wastes. Additionally, the August explosion also damaged two waste sorting and recycling facilities which further contributed to inefficient waste management in Lebanon (Al Tawil et al., 2023).

The “environmental degradation” that was an effect of the explosion was almost impossible to handle as Lebanon is going through this very strong economic crisis, and funding for repairs would have been around \$100 million (UN, 2020). Adding to this, Lebanon was not capable of swallowing the huge waste left behind by the explosion. The lack of preparation and response plans for such disasters in Lebanon made the disaster even more destructive exacerbated by the country’s limited, capacity to efficiently manage waste disposal (UN, 2020). This led to enormous amounts of waste being dumped in different regions not suitable for waste disposal. Consequently, the landfills in Lebanon reached maximum capacity, necessitating the construction of new landfill facilities.

In Lebanon, there exist two kinds of landfills: formal landfills and informal landfills. Formal landfills are properly sited, planned, and designed according to established regulations and guidelines. On the other hand, informal landfills are established randomly by members of the community without proper planning or adherence to regulations. The 'informal' Lebanese landfills are considered a very alarming issue (Hilal et al., 2015). They subject the environment to pollution as they are done with no prior study of infrastructure and the safety of the natural surroundings.

In fact, regulated landfills in Lebanon are limited, and their waste disposal capabilities exceed their original design capacities. The unsuitable waste management in those landfills led them to become short-lived and thus resulted in the destruction of the environment. The government, unfortunately, was unable to take hold of this issue, so household and other waste accumulated all over the country. As a result, the country witnessed many alarming and arising health and environmental issues. As researchers conclude, citizens whose homes are close to landfills, are more prone to the development of respiratory issues, illnesses, depression, and even memory loss (Singh & Farswan, 2019).

To put an end to this issue, urban plans must prioritize the creation of suitable and healthy residential areas. This would include siting hazardous facilities out of close proximity of human activities as well as providing sufficient barriers. The negative effects of landfills on human health and the ecosystem are well known, and limiting the siting of landfills near housing zones should be introduced as a regulation. Unauthorized landfill creation must be forbidden, and the landfills that already exist should be properly managed in order to decrease the harm they cause to the public and environmental health. Waste management requires a holistic approach, where both citizens' and nature's needs are taken into consideration.

Figure 11 illustrates the diverse types of waste management facilities in the Lebanese region. It displays landfills and open dumping areas, alongside sanitary facilities, thermal plants, and operational and non-operational facilities.

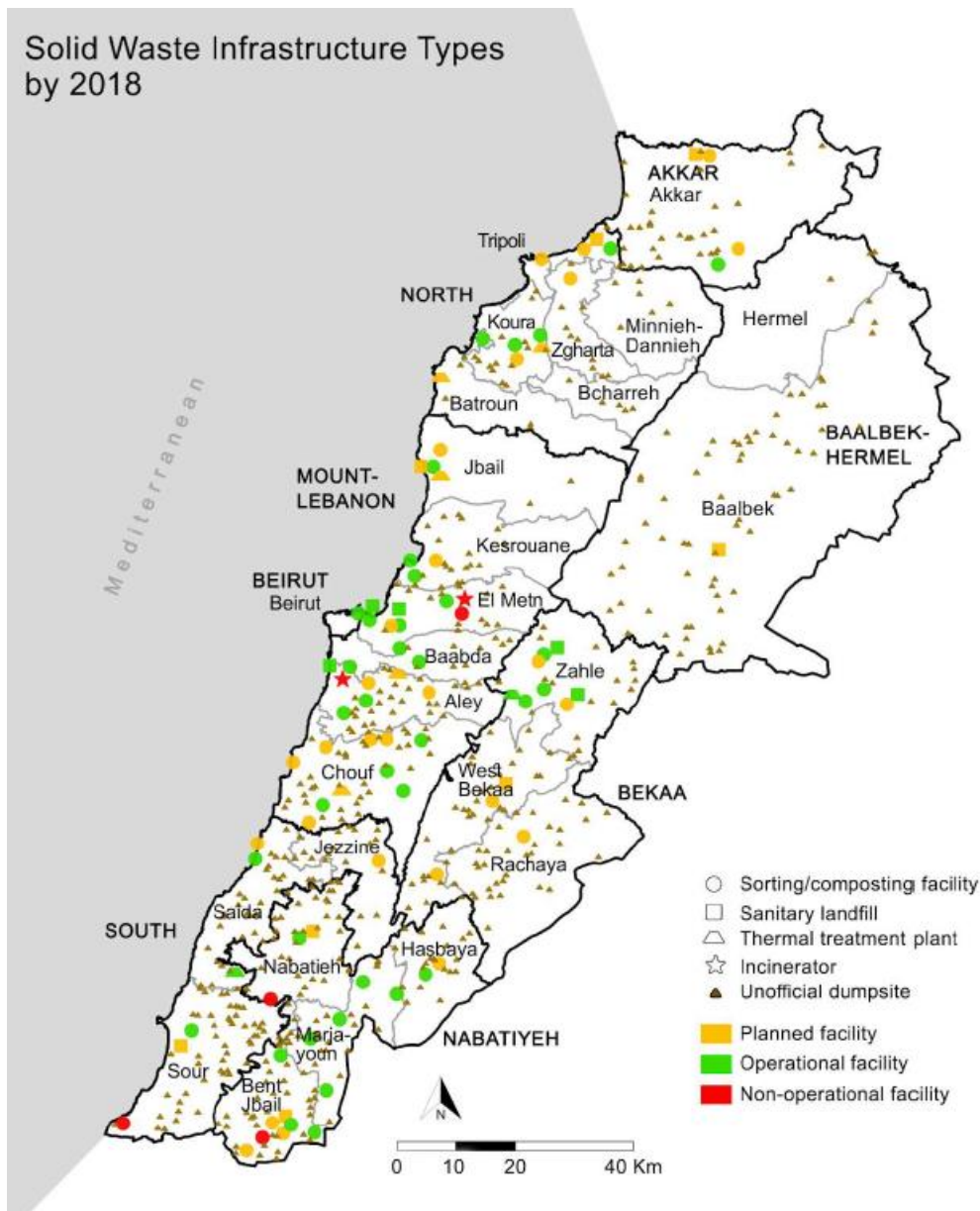


Figure 11: SWM types in Lebanon (Farah, 2020)

2.4 Situation of waste generation in Lebanon

Waste management practices in Lebanon are organized into three primary categories. Firstly, MSW encompasses the routine disposal of non-hazardous items by households and businesses. Secondly, Hazardous Waste includes materials with potential risks to human health and the environment, such as toxic chemicals, medical waste, and infectious materials. The third category,

Wastewater, focuses on the treatment and disposal of liquid waste originating from both domestic and industrial sources. Each waste category demands specific management strategies tailored to address the diverse challenges associated with SW, hazardous waste, and wastewater.

According to the UNDP report from 2011, SW represents more than 80% of the total waste generated in Lebanon. The primary sources of SW include households, restaurants, and street cleaning activities. In terms of the Lebanese waste composition (Figure 12), organic waste constitutes 50% of the SW, while paper and cardboard make up 17%, plastics account for 13%, metals contribute 6%, glass represents 4%, and miscellaneous materials make up 10% (UNDP, 2011).

Halwani et al. (2020) found that Lebanon generates an estimated 50,000 tons of hazardous SW annually. This waste encompasses a diverse array of types, including hazardous industrial chemicals, electronic waste, expired solid drugs and materials, various categories of healthcare waste, used tires, used batteries, and different forms of sludge, as reported by the UNDP in 2018., the MoE in 2006 highlighted additional challenges in managing waste categories, including SW generated by the olive oil industry, waste originating from slaughterhouses, construction and demolition waste, as well as bulky refuse. The disposal and handling of electronic waste and appliances further contribute to the complexity of Lebanon's waste management landscape.



Figure 12: *The Lebanese waste composition (UNDP, 2011)*

Waste generation in Lebanon is distributed among five localities, as documented by GIZ in 2010 (Table 2). Mount Lebanon has the highest waste generation, accounting for 40% of the total waste produced in the country. Conversely, South Lebanon & Nabatiyeh, as well as North Lebanon, have a relatively smaller impact, generating only 18% of the overall waste (GIZ, 2010). Beirut and Bekaa exhibit the lowest waste generation rates, contributing approximately 11% and 13% respectively (source, 2010). This percentage fluctuates depending on whether the location is urban or rural, as well as the distinction between the summer and winter seasons. This growth can be also attributed to factors such as population expansion, increased affluence, higher consumption levels, and a rise in tourism. Based on the assumption that this pattern persists, SW generation in Lebanon is projected to reach approximately 2.4 million tons by 2030 (UNDP, 2011).

Table 2: *The percentage of waste generation in each governance (GIZ, 2010).*

<i>Governance</i>	<i>Waste Generation</i>
<i>Mount Lebanon</i>	40%
<i>South Lebanon & Nabatiyeh</i>	18%
<i>North Lebanon</i>	18%
<i>Beirut</i>	11%
<i>Bekaa</i>	13%

As Lebanon's population steadily grows over the years, the evolving lifestyles of its inhabitants contribute to an increase in the generation of waste. Trends also show an increase in waste generation per capita. A comprehensive study conducted by Maalouf and El-Fadel (2019) revealed that the Greater Beirut & Mount Lebanon region produces a substantial volume of MSW daily, estimated to range between 2800 and 3000 tonnes. This translates to an approximate per capita generation of 1.3 kg/day. Maalouf and El-Fadel (2019) also shed light on the composition of this waste, revealing that it encompasses various categories of materials. Food waste constituted the largest portion, accounting for approximately 53.4% of the total waste generated. Glass waste comprised 3.4%, metals constituted 2%, nappies made up 3.6%, papers accounted for 15.6%, plastics amounted to 13.8%, textiles represented 2.8%, wood contributed 0.8%, and the remaining 4.6% encompassed miscellaneous items not falling under the aforementioned categories (Maalouf and El-Fadel, 2019) (Figure 13).

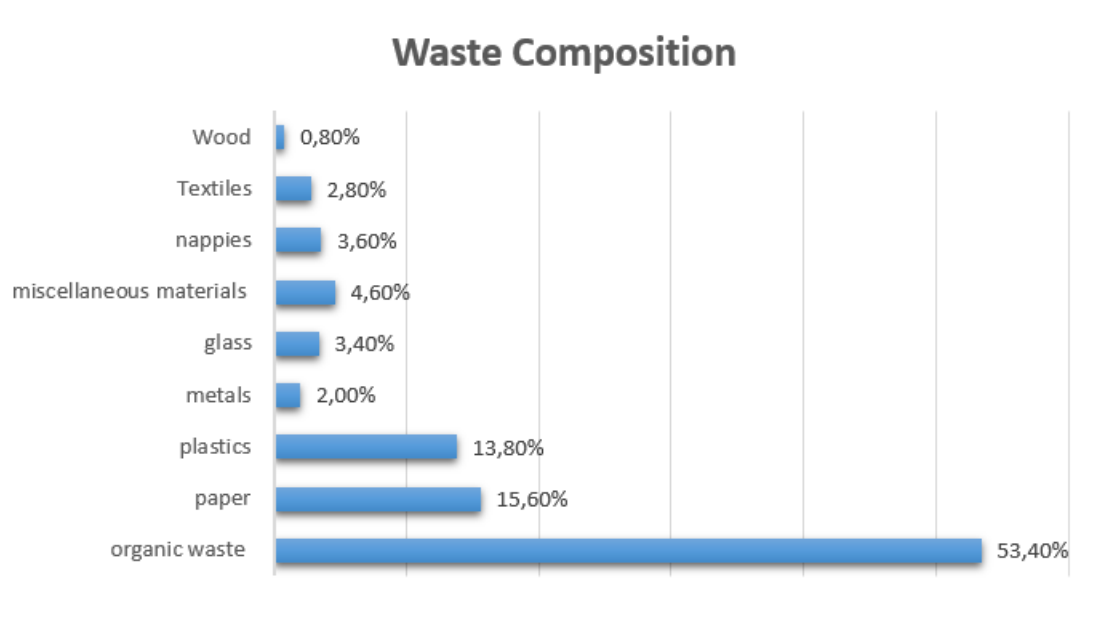


Figure 13: *The Waste composition in the Greater Beirut & Mount Lebanon (Maalouf and El-Fadel,2019).*

In the district of North Lebanon, the city of Tripoli has gained notoriety for its significant role in contributing to the persistent waste crisis affecting the entire country. A comprehensive study conducted by Halwani et al. (2020) has extensively documented the Tripoli dumpsite, revealing an average annual intake of 158,720 tons of waste until the year 2017. This substantial volume underscores the gravity of the waste predicament within the city. The consistent and sizable influx of waste not only signals the magnitude of environmental challenges faced by Tripoli but also highlights the city's struggle to efficiently manage and regulate waste disposal. Such a substantial and recurring quantity of waste indicates underlying systemic issues in waste management practices, potential inadequacies in infrastructure, and perhaps a deficiency in sustainable policies within Tripoli. Over time, there has been a discernible surge in waste accumulation at the Tripoli landfill. Statistical data from sources like UN-Habitat in 2016 and UNEP in 2009 depict a

consistent upward trend in daily waste averages. Specifically, between 2010 and 2014, the landfill recorded an average intake of 350 tons per day.

The primary source of waste deposited in Tripoli's landfill consists predominantly of domestic waste, making up the largest proportion. As emphasized by UNEP in 2009, approximately 90% of the collected waste originates from residential sources, underscoring the significant role played by households in waste generation. The remaining fraction encompasses various categories, including street refuse, remnants from poultry and slaughterhouses, as well as industrial and agricultural waste, as highlighted in the comprehensive study conducted by UN-Habitat (2016).

Chapter Three: Methodology

The methodology section in this thesis provides a comprehensive explanation of the research methods and data collection strategies employed in this study. This chapter covers the research techniques used, the criteria used for the interviews, along the ethical principles followed during the study.

3.1 Unit of Analysis

As for the unit of analysis of this study, it is determined by three factors: geographical boundaries, theoretical scope, and period. To begin with, the geographical focus is limited to Lebanon, and the theoretical basis is based on the literature on circular economy and sustainable waste management. The goal here is to look into the influence of landfills on the surrounding areas in Lebanon, as well as the country's sustainable waste management procedures, from the beginning of the waste crisis in 2015 to the present day. The research took around twelve months, from December 2022 to December 2023.

3.2 Research Design

The establishment of circular economy principles in waste management is more and more crucial in reducing the negative effects of landfills on the environment and the community. To handle this issue in Lebanon, which is a developing country struggling with waste management, a four-stage research plan has been developed (Figure 14). The first stage in this plan focused on conducting a comprehensive literature review to gain an understanding of the effects of landfills on the environment, society, and the economy. In addition to that, the literature review sets the foundation for the research by emphasizing the definitions of SWM and circular economy. A literature review, as suggested by Gillham (2010), is an essential step in research that identifies research gaps and steers research toward finding an authentic answer. This study's literature review included works

ranging from academically published works to legal and public documents, in addition to governmental and non-governmental department reports.

The second stage involves preparing interviews with pre-selected individuals when the evaluation is completed. These individuals were identified as stakeholders from waste management organizations in Lebanon. Criteria for the questionnaire and the interview framework were also defined in this stage.

The third stage was also related to interviews where stakeholders, including private, public, and environmental professionals were interviewed, which helped in achieving a deep understanding of the benefits and drawbacks of the SWM system at both the national and local levels in Lebanon can be understood. Cohen and Crabtree (2006) explained that in the interviewing stage, open-ended questions can be used in semi-structured interviews so that the interviewees get to give more thorough responses and spark in-depth discussions. These types of interviews have many positive effects, as it becomes possible to have a more thorough understanding of the SWM system, where different types of stakeholders were interviewed, ensuring that a variety of points of view were taken into consideration. Additionally, what could be gained from the interviews was insight into potential remedies for the system issues.

The fourth and final stage involved analyzing all the collected data to address the research questions and draw conclusions about the best system option.

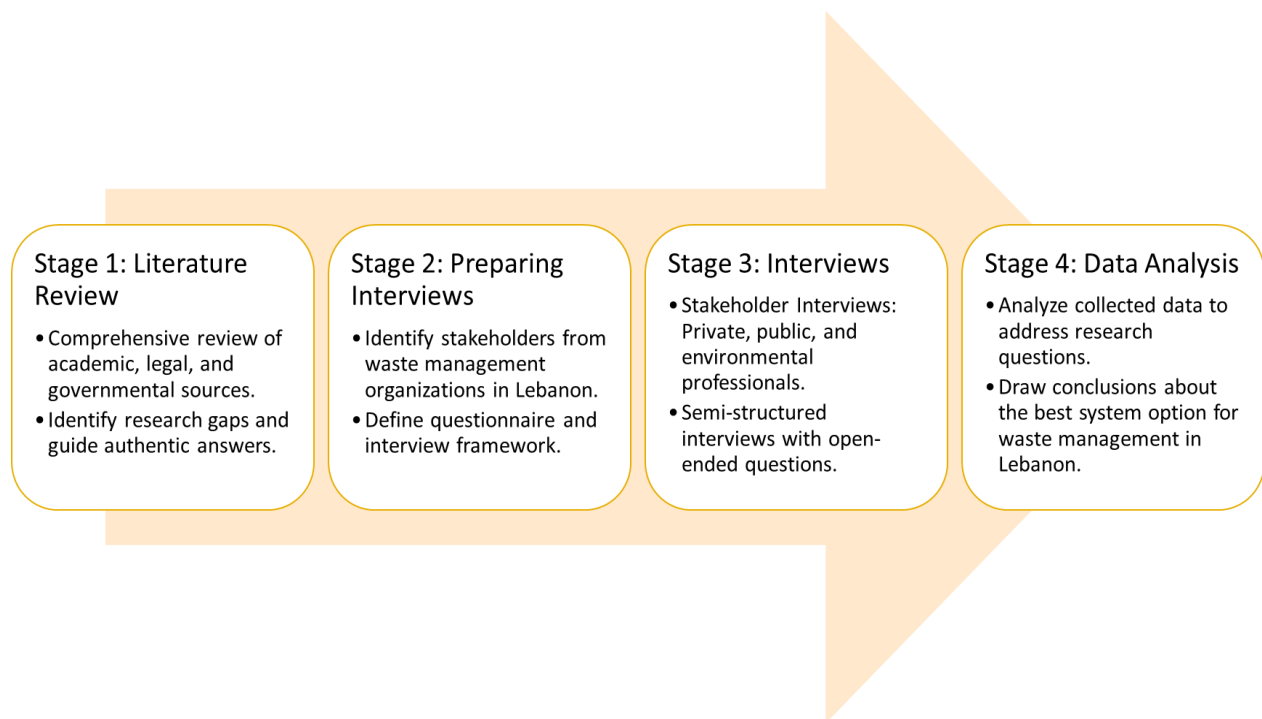


Figure 14: *Four-Stage Research Plan*

3.3 Data Collection

Moving to the qualitative research methodology used by this study: it is a structured and organized approach used in order to collect data from multiple sources. The primary objective of this methodology is to provide a comprehensive understanding of the SWM sector in Lebanon. By utilizing qualitative research methods, the study aims to identify potential linkages and approaches that can effectively address the existing gaps and challenges in Lebanese SWM.

As discussed previously, this research adopted a three-stage technique for data collection, while focusing in the first stage on secondary sources of information. This research analyzed the effects landfills have on the environment and community, as well as the basics of SWM. In the second phase, the main data was collected through interviews done with specialists and policy advisors in order to gain insights into the advantages, and disadvantages of the current system in use and to identify any areas for future improvement. And finally, assessed critical recommendations for

improving the sector-based academic literature, reports, and open discussions with experts in the field of SWM in Lebanon. This methodology adds to this research a comprehensive and detailed analysis of the SWM sector in Lebanon while highlighting any space for development and finding any potential solutions to address the existing gaps in the area of study.

3.3.1 Literature Review

The literature review has revealed essential insights concerning the environmental and socio-economic impacts of waste management practices, with a specific emphasis on the repercussions of landfills. Additionally, it has encompassed the fundamental concepts of waste management. The knowledge gleaned from this review will play a pivotal role in scrutinizing the outcomes obtained through the primary research methods employed in this study.

In the process of interpreting and applying the literature review findings to the study area, a systematic approach has been taken. The review initiates by elucidating the impact of landfills, aiming to comprehend the potential adverse consequences that Lebanon might face without a comprehensive understanding of its current waste management situation. Subsequently, it delves into the elucidation of key concepts in waste management, encompassing both general challenges faced by the field and specific insights into the present practices and challenges within the Lebanese waste management landscape.

This foundational understanding is paramount for the subsequent comparative analysis. By scrutinizing and contrasting the literature findings with empirical data acquired during interviews, the study seeks to validate and contextualize the theoretical insights within the socio-cultural and environmental context specific to Lebanon.

The impacts addressed through this analytical approach encompass the identification of challenges in waste management practices, both at the individual and systemic levels. The study aims to align

the theoretical insights garnered from the literature with the tangible challenges confronted in Lebanon, ultimately proposing practical recommendations to mitigate these impacts.

It's noteworthy that the literature review primarily focused on peer-reviewed English journals, utilizing specific keywords such as 'solid waste management,' 'landfills,' 'environmental impact,' and 'Lebanon.' The comprehensive search for relevant research and studies was conducted on platforms like Google Scholar and other pertinent databases, employing a meticulous multi-stage review process.

3.3.2 Semi-structured Interviews

In the summer of 2023, a series of semi-structured interviews were conducted to identify and sufficiently understand the challenges and opportunities within Lebanon's waste management sector. This was required to develop suitable waste management strategies in the pursuit of sustainable practices. The interviews took place between June and August 2023 and involved a diverse set of stakeholders from various sectors: Governmental, Private, NGOs, and Social Entrepreneurship. The structured format included predefined questions crafted in advance, providing a framework for the interviews while also allowing room for spontaneous, open-ended discussions (Appendix A).

Below is Table 3, illustrating the number of interviews conducted across different sectors.

Table 3: *Number of interviews in each sector*

<i>Number of Interviews</i>	<i>Type of the facility</i>
3	Private sector
3	Governmental
2	NGO
2	Social entrepreneur
10	Total

Firstly, three private companies were selected as interview subjects, offering valuable insights into the challenges faced by the private sector in waste management. The initial interview featured the founder of a company specializing in the collection of recyclables from residents, with the intention to sell these materials to recycling companies. The second interview involved the founder of a recycling company, known for its expertise in recyclable waste and its collaboration with sorting facilities on a national scale. Lastly, the third interview engaged the owner of a composting company, renowned for its numerous partnerships with the governmental sector, particularly in the management of organic materials.

In a separate set of interviews, three municipalities were the focus. These interviews aimed to shed light on the challenges and practices encountered by the public sector in waste management. The selected municipalities spanned diverse geographical areas, each marked by distinct cultural and waste management practices. These interviews were facilitated by experts in waste management, specifically the assistants to the mayors who possess specialized knowledge in this field.

To broaden the perspective and search for innovative solutions, an additional set of four interviews was conducted. This round featured two environmental NGOs and two social entrepreneurs, all deeply motivated to discover sustainable solutions to address Lebanon's ongoing waste crisis.

Figure 15 displays the diverse geographical locations of the facilities interviewed in Lebanon. Meanwhile, Table 4 presents the interview locations and corresponding codes used in the thesis to maintain the anonymity of the interviewees throughout the results.

The interviews took place through both in-person and online formats. Some interviews occurred on-site at the workplaces or offices of the interviewees, while others were conducted through online platforms like Zoom and Google Meet. The decision to use online platforms was often due to logistical and time constraints.

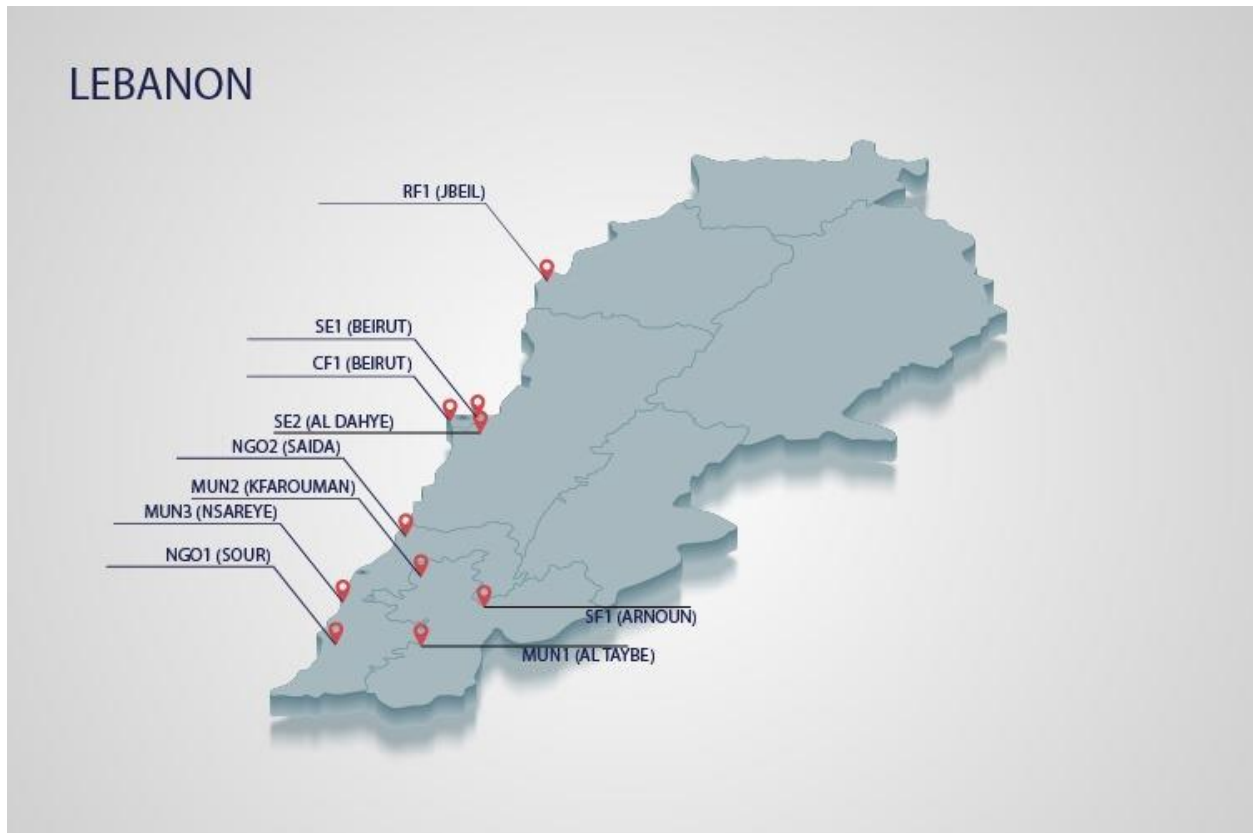


Figure 15: *The geographical locations of the interviewed facilities in Lebanon.*

The interview questions focused on multiple facets of Lebanon's existing SWM practices, exploring both the advantages and disadvantages of these methods. The objective was to identify potential solutions for the persistent challenges within the country's waste management system. Consequently, the majority of interviews revealed that various facilities are grappling with similar challenges in their operations.

Table 4: *List of Interviewees*

<i>No.</i>	<i>Agency/Organization</i>	<i>Code</i>	<i>Location</i>
<i>1</i>	Municipality 1	MUN1	Al Taybeh
<i>2</i>	Municipality 2	MUN2	Kfarouman
<i>3</i>	Municipality 3	MUN3	Nsareye
<i>4</i>	Environmental NGO	NGO1	Sour
<i>5</i>	Environmental NGO	NGO2	Saida
<i>6</i>	Recycling facility	RF1	Jbeil
<i>7</i>	Sorting facility	SF1	Arnoun
<i>8</i>	Composting facility	CF1	Beirut
<i>9</i>	Individual initiatives / Social entrepreneur	SE1	Beirut
<i>10</i>	Individual initiatives / Social entrepreneur	SE2	Al Dahye

3.4 Data Analysis

The analysis of the data was a systematic process involving the use of the Atlas.ti application to code and analyze the interviews. The first step involved transcribing all the interviews, and meticulously recording every detail. These transcriptions were then consolidated into a comprehensive Word document.

To facilitate more effective data analysis, the Word document was uploaded to the Atlas.ti platform. This platform allowed for the creation of a structured coding system, enabling the organization and categorization of the interview content. Each interview was systematically reviewed and relevant quotations, as well as important phrases, were coded into specific subgroups.

These subgroups were further organized into four overarching main categories, providing a hierarchical structure for the data. This methodical approach to coding and categorization proved invaluable in making sense of the extensive information obtained through the interviews.

Ultimately, this process allowed for a comprehensive understanding of the data, enabling the creation of a clear and logical framework for readers. The scheme presented below (Figure 16) illustrates the coding groups and their corresponding subgroups, offering a visual representation of the organization and structure of the data analysis.

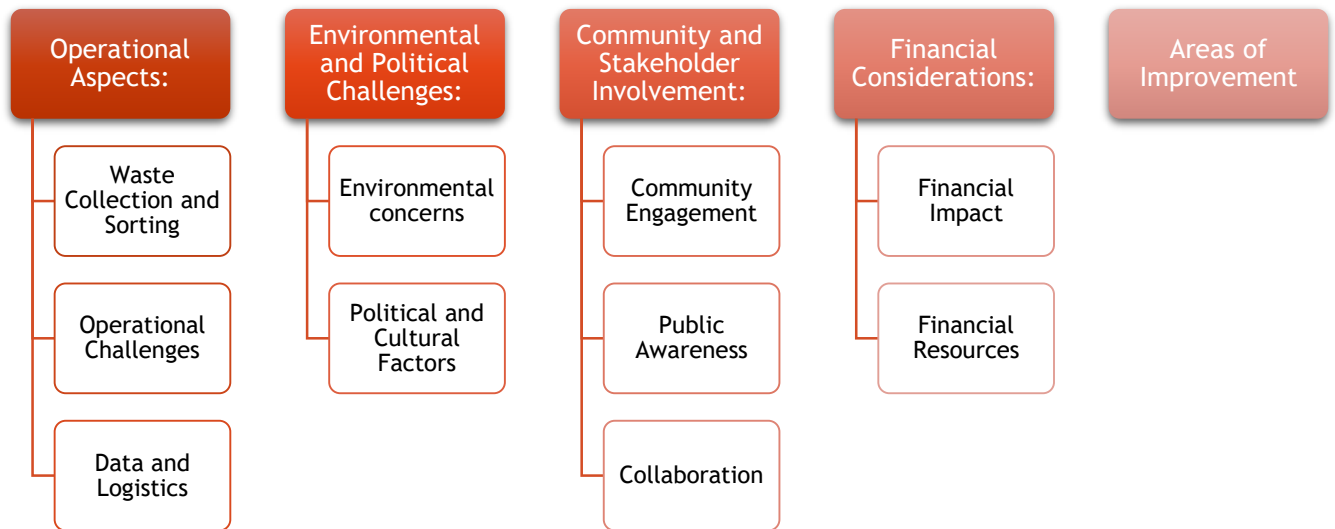


Figure 16: Hierarchical Coding Scheme: Groups and Subgroups

3.5 Ethical Considerations

In all research, ethical considerations are of high importance, especially in a master thesis where data collection is a key aspect. In this thesis, to ensure that data collection is fully ethical and approved by ethical principles, multiple steps were taken. The first step was obtaining consent from all the interviewees while also explaining to them the purpose of the study and the potential risks and benefits. Then, ensuring confidentiality where participants were protected by pseudonyms and all data was stored securely. After that, it was clear to all participants that their participation is entirely voluntary, and if they'd like to withdraw from participation then they're free to do so at any time without any negative consequences. Additionally, it was clear that the recorded information and collected data would be deleted after submission and completion of the thesis.

All in all, with the help of these additional ethical considerations, aim to conduct data collection in a way that is not only responsible and ethical but also culturally sensitive and unbiased, which will contribute to the credibility and validity of research findings.

Chapter Four: Results & Analysis

This chapter presents the results and analysis of the study.

4.1 Operational Aspects:

In this section, an exploration is conducted into the operational aspects utilized within sorting facilities situated in different regions of Lebanon, based on insights provided by interviewees. The analysis commences with a thorough examination of the fundamental processes, methods, and practices that form the foundation of these facilities' operations. Additionally, a detailed analysis is undertaken to explore the operational challenges faced by these facilities, shedding light on the obstacles encountered in the pursuit of their operational goals.

4.1.1 Waste Collection & Sorting:

Waste collection practices in Lebanon are quite consistent across regions, with a subtle difference between government-run operations managed by municipalities and those handled by the private sector. Typically, waste sorting starts at the household level, where residents separate waste into two or three categories: organic, recyclables, and non-recyclables. This practice is known as 'at-source separation.' In some municipalities equipped with organic waste facilities, the waste is further divided into three categories, while those without such facilities sort waste into two categories.

To address the challenge of low public awareness regarding waste separation practices, as pointed out by Interviewee MUN3, and the resulting difficulties in maintaining cleanliness and accurate sorting of waste into designated categories, municipalities have considered providing visual aids, such as pictures, to attach to each sorted bin. This approach will help individuals better understand which items should be placed in each bin and improve their knowledge of the waste separation process. Moreover, Interviewee MUN2 stressed the significance of enhancing household sorting

efficiency by involving young and active volunteers in awareness campaigns aimed at educating residents about proper waste separation. Additionally, residents are provided with differently colored bags to aid in the separation process.

MUN1 provided insights into the waste collection process, detailing that bag collection takes place weekly using a garbage collection truck. MUN1 emphasized the manual sorting conducted at their factory to differentiate between recyclable and non-recyclable items. The facility manages an average of 25 tons of waste daily, sourced from seven municipalities. MUN1 then highlighted the presence of a compactor for material compression and noted the established collection system. The interviewee underscored the manual sorting involved in the remaining tasks. This manual waste sorting practice is common in municipalities with recycling facilities, fostering efficiency and creating local job opportunities. Additionally, these facilities employ transportation vehicles and compaction machinery to streamline operations and minimize costs. Following sorting, recyclable materials are individually categorized, separated, and compacted using compaction machines, preparing them for sale to other factories that purchase recyclables.

In the private sector, they employ a distinct approach to waste collection, driven by their commitment to reduce environmental impact and maximize profits through the collection and reuse of recycled material. Rather than undertaking recyclable collection themselves, private companies, as exemplified by CF1, collaborate with municipalities to offer guidance on waste reduction within households. This partnership allows municipalities to assume responsibility for waste collection from their residents, subsequently selling the collected recyclables to private companies such as the recycling facility in Beirut (RF1) and the composting facility (CF1). Notably, RF1 and CF1 expressed their willingness to directly purchase recyclables from municipalities to facilitate recycling processes, utilizing the recycled materials for various

applications, such as manufacturing plastic beams and other products. RF1 added: "*And from those plastic beams and sheets, we can create tables, stools, benches, picnic tables, and cladding for interior architecture*". In contrast, SF1 and SE1 employ different methodologies for recyclable collection, operating a company center where individuals can submit recyclable materials and receive compensation in return. NGO1 argued that setting up drop-off points throughout the cities can encourage people to participate in the sorting process.

NGO1 and NGO2 shed light on a prevalent challenge in municipalities, which is the management of non-recyclable waste—materials that lack recyclability. The conventional approach for dealing with this type of waste involves its disposal in landfill sites. Unfortunately, these landfill sites exhibit informal characteristics and resemble unregulated dumpsites.

Notably, these makeshift landfill sites are undoubtedly not equipped with liners or capping, resulting in extensive pollution concerns. They contribute to water pollution, as leachate from these sites can contaminate nearby groundwater sources. The lack of proper containment also leads to litter, attracting birds and rodents, which can further exacerbate environmental problems.

Furthermore, the absence of formally authorized landfills adhering to established environmental protection standards exacerbates the complexities associated with waste management, effectively making makeshift landfills the primary, and often the only, available disposal option. This lack of rehabilitation or proper management raises concerns about the environmental impact and potential risks to public health.

In some cases, due to the limitations of these informal landfill sites, operators may resort to burning waste, leading to air pollution issues in addition to the existing environmental challenges. This highlights the urgent need for more sustainable and environmentally responsible waste management practices in these municipalities.

4.1.2 Operational challenges:

The effectiveness of waste sorting and recycling facilities in Lebanon experienced significant fluctuations in the years leading up to 2019 and the subsequent challenges that arose. Initially, most of these facilities operated smoothly with relatively few difficulties. However, in 2019, a series of adverse events marked a turning point. According to MUN3, the progress made by these facilities was notably disrupted in 2019 due to the confluence of two major factors: the challenges presented by the COVID-19 pandemic and Lebanon's severe financial crisis. The resulting financial strain made it increasingly difficult to sustain funding for waste management projects.

During this critical year, Lebanon faced a substantial inflation rate, compounding the challenges faced by waste facilities. Operational difficulties emerged alongside the struggle to secure adequate financial resources. The onset of the COVID-19 pandemic further compounded these issues, forcing employees to stay at home and leading to waste accumulating on the streets. Ultimately, this accumulation prompted residents to resort to open burning of waste near their homes.

NGO1 and NGO2 corroborated these observations, emphasizing that the adverse impact on facility operations was not solely due to the COVID-19 pandemic. The financial crisis and the devastating explosion in Beirut exacerbated the situation. These events led to a surge in waste disposal without proper sorting or recycling, compounding the challenges faced by waste management facilities in Lebanon.

Within the operational scope of numerous municipalities, which MUN2 and MUN3 highlighted, operational constraints within waste management facilities were at times aggravated by the presence of administrative routines and regulatory requirements. The resolution of any facility-related issues necessitated obtaining administrative approvals from higher authorities, leading to

intermittent interruptions in operations as approvals were awaited. This administrative process often resulted in delays in promptly addressing operational challenges. This issue was not facing the private companies since they did not have to refer to the higher authorities in case they had any problems.

Operating waste management facilities encountered also an additional challenge which is related to employment difficulties, as highlighted by MUN2. This challenge stemmed from the prevailing societal attitude towards waste-related work. MUN2 noted that "*[...] employing individuals for this facility posed difficulties due to the prevailing societal attitude against working with waste.*" In Lebanon, cultural factors played a significant role in shaping perceptions of waste-related employment. Many Lebanese individuals hesitated to work in this field, viewing it as undesirable or even shameful. This cultural stigma surrounding waste-related jobs presented a significant barrier to recruiting and retaining employees for waste management facilities, as stated by SE2 & NGO1. SE1 provided further insight into this issue, noting that "*the issue of employment stemmed from the fact that individuals were not being compensated adequately to cover their basic expenses. [...] As a result, many were reluctant to join our workforce, as the wages offered were insufficient to support their livelihoods.*" Inadequate compensation compounded the challenge of attracting and retaining skilled personnel within the waste management sector, further exacerbating the employment difficulties faced by these facilities.

Apart from employment challenges, the electricity supply posed a significant obstacle to the smooth operation of facilities in many areas. The facilities did not receive a continuous 24-hour supply of electricity due to infrastructure shortcomings. This situation, as noted by SE1, necessitated the adoption of costlier measures to ensure a steady power source. Some facilities

resorted to purchasing their own electricity generators, a costly investment that also required fuel for operation.

On the other hand, certain facilities, like the one in the Nsareye municipality (MUN3), pursued an alternative approach by implementing renewable energy solutions. While this endeavor was also associated with considerable expenses, they managed to secure support from NGOs to fund their renewable energy initiatives.

4.1.3 Data & logistics:

Both the private and governance sectors face considerable challenges in formulating effective waste management plans, with a key obstacle being the scarcity of essential data necessary for informed decision-making. The specific deficiency lies in the lack of data regarding the precise volume of waste generated in each area and the corresponding composition percentages. NGO2 and SE2 underscored the limited availability of data related to household waste types and quantities, acknowledging ongoing efforts to enhance data collection in this domain. SF1 echoed these concerns, emphasizing the challenge in gathering information about the quantity and types of waste in each area, attributing this to insufficient awareness about the importance of compiling such statistics. The lack of public accessibility to existing data further compounds the issue.

Furthermore, the fragmentation of data collection efforts, with each sector independently collecting and retaining data without centralized access, complicates the development of comprehensive waste management plans. MUN1 emphasized that this fragmentation arises from a lack of awareness regarding the significance of having such data and understanding how it can be effectively utilized to construct well-structured waste management plans. MUN1 then explained that limited data and information become inaccessible due to the absence of prioritization in the

collection process, indicating a failure to accord sufficient importance to gathering essential data, resulting in an inadequate and unavailable dataset.

In addition to data fragmentation, logistics, and transportation have emerged as significant challenges within the waste management sector due to their substantial operational costs, which can be daunting even with financial support. CF1 added that investing in new technologies for waste management facilities requires substantial financial backing, a challenging endeavor exacerbated by the economic instability caused by the ongoing inflation crisis in Lebanon. Managing the necessary financial resources for such advancements has become increasingly arduous.

Furthermore, CF1 emphasized that the challenge of covering transportation fuel expenses, often in US Dollars, is exacerbated by the simultaneous impact of inflation and the depreciation of the Lebanese Pound. This compound effect further intensifies the financial challenges linked to funding transportation operations. Inadequate financial support also hinders the adoption of a diverse fleet in waste management. Notably, the crucial role played by specialized trucks with compaction arms in collecting landfill waste contributes to the overall efficiency of waste collection by enabling the gathering of larger volumes in a single operation. However, the high cost of these trucks makes them unaffordable for many facilities.

In response to the escalating transportation costs, MUN2 and MUN3, in collaboration with other municipalities, have explored an innovative solution: the adoption of a new small vehicle called the "TukTuk." This vehicle operates on solar energy, presenting a promising avenue to reduce transportation expenses. This inventive approach holds the potential to alleviate some of the financial burdens tied to logistics and transportation within the waste management sector.

4.2 Environmental and Political Challenges:

In the subsequent section, a thorough examination will be conducted on sorting facilities and the challenges they face concerning both political and environmental issues. The goal is to explore these obstacles with the aim of gaining a more profound understanding of the specific problems necessitating resolution.

4.2.1 Environmental concerns:

In the midst of the ongoing waste crisis in Beirut, precipitated by environmental challenges, an immediate response is imperative. The current situation vividly underscores the necessity for proactive intervention, given the authorities' failure to enact effective measures, thereby allowing the crisis to intensify. This predicament reveals systemic shortcomings, shedding light on the local government's lack of preparedness and inadequate response to the burgeoning waste problem. It may also be indicative of a deficiency in comprehensive waste management policies and infrastructure. Consequently, the crisis continues to worsen, impacting the quality of life for Beirut's residents, the environment, and the city's overall reputation.

The proliferation of waste in the streets has become alarmingly widespread, prompting the interest of private entities, as alluded to by SE2. This signals a service gap within the government and an opportunity for synergistic collaboration between the public and private sectors to address this predicament. While private entities can offer immediate relief to some of the challenges at hand, a more holistic and coordinated approach is necessary to establish a sustainable solution. Additionally, NGO2's findings emphasize the burgeoning issue of unauthorized dumpsites in the Beirut area, with no party assuming responsibility for their proper removal or disposal. This predicament suggests either an absence of enforcement of existing regulations or potentially weak regulatory frameworks governing waste disposal. The mounting number of these illicit dumpsites

underscores the urgent need for enhanced monitoring and enforcement mechanisms to deter illegal waste dumping. Furthermore, this escalating issue has substantially eroded residents' trust in the government's capacity to tackle the problem, leading some to resort to open dumping and burning as makeshift methods of waste management. This not only signifies a breakdown in the government-citizen relationship but also poses a grave environmental concern. Both SE2 and MUN1 have corroborated this observation, highlighting that areas lacking dedicated waste facilities often resort to waste burning, perpetuating environmental issues and causing harm to nearby neighborhoods. These concerns also extend to public health risks associated with mismanaged waste, including the potential for disease spread and air pollution stemming from unregulated waste burning, as emphasized by NGO2.

SE1 has further clarified that there are no authorized landfills in numerous regions throughout Lebanon, including areas like South Lebanon, exacerbating the situation. This absence of authorized disposal sites has led to an increase in unauthorized landfills and open dumping practices across municipalities, compounding the waste crisis's complexity. In the vicinity of NGO2, there is an open dumping site that poses a significant environmental threat. As NGO2 pointed out, *"The existence of a landfill with 100,000 tons of waste is akin to a ticking environmental time bomb, posing a threat to the adjacent area."* This threat extends to the groundwater, soil, air, and the surrounding environment due to the absence of environmental impact assessments that should have been conducted before any dumping activities occurred.

SF1 provided valuable insights into the environmental consequences of waste management processes, emphasizing the pivotal role of waste reduction in alleviating the carbon footprint associated with such practices. Specifically, SF1 highlighted the contributions of landfills and incineration to climate change through the release of GHG. Landfills, in particular, were identified

as sources of methane, a potent GHG with a much higher heat-trapping capacity than carbon dioxide, produced during the decomposition of organic waste. In the context of Lebanese landfills, a significant issue is the lack of adequate gas collection systems, resulting in the uncontrolled release of methane and exacerbating global warming, thereby contributing to the broader challenge of climate change.

On the other hand, incineration, despite being a waste disposal method, emits various pollutants and GHG, including carbon dioxide, into the atmosphere. This practice adds to the overall environmental impact associated with waste management. The crucial connection lies in the fact that reducing the volume of waste sent to landfills or incineration facilities directly corresponds to a decrease in GHG emissions during waste decomposition or incineration. This reduction is vital to the collective effort to mitigate climate change.

4.2.2 Political & Cultural factors:

The intricate political landscape in Lebanon has introduced multifaceted challenges to waste management, transcending mere operational and environmental concerns. These challenges are further compounded by political divisions, competing interests, and bureaucratic impediments, as highlighted by SF1. Consequently, the formulation of effective waste management policies and the implementation of sustainable solutions have been significantly hampered by these intricate political dynamics.

Reaching a consensus on pivotal waste management issues has proven to be an arduous task in Lebanon. This encompasses critical matters such as establishing environmentally friendly landfill sites for the effective management of non-recyclable waste and energy utilization, as emphasized by NGO2: *"The current politicians in power have been unable to reach a clear consensus on establishing an environmentally friendly landfill to handle non-recyclable waste effectively and*

harness its energy potential." The persistent political conflicts have stymied agreement on these essential initiatives.

Furthermore, effective communication with key stakeholders, including politicians and individuals supportive of waste separation, has proven challenging. Despite expressing willingness to participate and assist in waste separation efforts, there is often a disconnect between stated intentions and actual actions. Many individuals voice support for these initiatives in principle but fall short in practical implementation, resulting in insufficient backing for waste-sorting endeavors. RF1 highlighted this discrepancy, noting that individuals may endorse such initiatives in theory but fail to take necessary steps for effective waste sorting when it comes to practical implementation.

SE2 insightfully pointed out that achieving a more balanced distribution of power and authority among ministries, particularly strengthening the MoE, could be a crucial step in fostering effective waste management practices in Lebanon. This observation indicates that addressing power imbalances and empowering the MoE may play a pivotal role in overcoming political challenges and enhancing waste management practices in the country.

4.3 Community and Stakeholder Involvement:

In the upcoming section, an exploration will be conducted into the essential dimension of community and stakeholder involvement in waste management. This section will cover the participation of communities and stakeholders, underscoring the significance of their engagement and its role in shaping effective waste management practices.

4.3.1 Community Engagement:

The key driver for enhancing community engagement with municipalities and other sectors involved in waste management is the establishment of trust. Nevertheless, Lebanon faces a

significant challenge in this regard, as a substantial portion of its citizens lack trust in the government and its waste management initiatives. This absence of trust hampers their willingness to cooperate, primarily due to concerns related to transparency and a general unawareness of the government's waste management plans. In addition, there is widespread frustration over inefficiencies in the waste management process, with separated waste often being commingled during transportation and inadequately handled. MUN2 emphasized the importance of trust, stating, *"The trust established between all parties involved empowers us to collaboratively address any potential challenges, adapt to evolving circumstances, and make informed decisions that align with the overarching mission of the project."* This trust in municipal leaders and officials plays a pivotal role in driving successful partnerships. When residents have confidence in the competence and dedication of those responsible for environmental initiatives, they are more likely to actively engage and contribute to achieving common goals. The presence of this trust is a direct result of the capable and responsible individuals working within the municipality, particularly those overseeing waste sorting and environmental programs as mentioned by NGO1.

One approach to address this issue is to enhance community involvement in the waste management process. This can be achieved by raising awareness and educating the community about the significance of waste sorting and recycling. SF1 offered a practical suggestion, proposing a competition among neighborhoods to encourage the adoption of the best waste-sorting practices. Neighborhoods that effectively sort and manage their waste while maintaining cleanliness and aesthetics, such as by painting their streets, would compete for recognition and rewards. SF1 emphasized, *"The interactions between these projects and their respective communities are a true testament to the power of grassroots engagement. Residents not only willingly participate in waste separation but also take pride in contributing to the well-being of their environment."* This

underscores the positive impact of community-driven initiatives and the willingness of residents to engage in waste separation and environmental betterment actively.

4.3.2 Public Awareness:

Cultural considerations are pivotal in the context of raising awareness among residents. SE1, MUN1, MUN2, and NGO2, exhibit varying levels of readiness when it comes to recycling culture and awareness in their region. In SE1's facility region in Beirut, the pre-existing recycling culture and high awareness levels meant that residents were receptive to the guidance of an authoritative entity in managing the recycling process. As articulated by SE1, "*Community awareness-raising efforts were relatively successful, as some residents already had a recycling culture and sufficient awareness to engage with us. However, they were looking for an authoritative entity to manage the process. As we initiated the project, they began to place trust in us and collaborate directly.*"

In contrast, regions such as NGO2 have encountered notable difficulties in raising awareness and instigating changes in residents' daily routines to promote waste sorting, even in the face of extensive awareness campaigns that specifically target educational institutions. This predicament is evident as MUN1 pointed out that the implementation of source separation faces challenges due to a lack of awareness within communities and minimal participation from individuals interested in properly sorting their waste. Regrettably, initiatives aimed at enhancing awareness have not yielded the anticipated outcomes in this scenario. Another contributor, SF1, emphasized that there is currently a deficiency in awareness and willingness within the decentralized public sector to engage in such partnerships or implement this approach. The overarching issue here is the challenge of public awareness and the integration of waste sorting into daily life. This challenge is particularly pronounced because a majority of the population remains oblivious to the significance of this matter and does not perceive an issue with discarding waste on streets rather

than sorting it at home. Furthermore, many residents are uninformed about the potential environmental and economic benefits that efficient waste sorting can bring about.

CF1 has put a valuable suggestion for addressing this issue through educational initiatives. The primary objective is to inform and educate the community about the importance of waste separation at the source. This entails teaching individuals the distinctions between recyclables, organic waste, and non-recyclable materials. The ultimate aim is to cultivate a culture of responsible waste management, empowering individuals to contribute to environmental sustainability. Emphasizing educational institutions, especially in educating the younger generation about a sustainable lifestyle, is recognized as the most effective approach to instilling a sense of responsibility regarding this issue, ensuring its integration into their daily routines. MUN1 emphasized, *"Regrettably, we often allocate only a limited timeframe to education, sometimes overlooking its lasting effects. It's essential to offer practical lessons, not just theoretical ones, to individuals and students."*

4.3.3 Collaboration:

Ensuring the effective implementation of a waste management plan and fostering active participation from residents and all relevant stakeholders hinge on robust collaboration. The more the community is engaged in the process, the more successful the outcomes will be, particularly concerning the source separation of waste. Collaboration between the public and private sectors is pivotal in enhancing community involvement, as underscored by SF1: *"As a private company, without municipal support, we don't achieve satisfactory outcomes to address the waste issue adequately."*

Municipalities play a significant role in bolstering and optimizing the work of private enterprises. They provide essential support for projects and elevate overall operational efficiency, often

offering crucial financial support essential for long-term sustainability. While private companies serve as linchpins in addressing immediate waste concerns while laying the groundwork for a more sustainable future in waste management. Their primary objective extends beyond short-term fixes and strives to cultivate a deeper sense of environmental consciousness among local residents. By involving private entities, these initiatives aim to transform the community's perspective on waste management. They act as catalysts, inspiring individuals to view waste management as a collective responsibility that transcends simple trash disposal.

On the other hand, the governmental sector complements these efforts by collecting waste and working to increase household participation in waste sorting. The collected waste is then sold to private sectors, creating a win-win situation where all parties benefit. Simultaneously, this collaborative approach leads to the implementation of a more effective waste management plan in the area.

SE1 further underscores the importance of this collaboration by stating, "*By working in tandem with municipalities and adhering to rigorous quality control measures, we contribute to the sustainable management of recyclable materials, reducing environmental impact and supporting the circular economy.*" This highlights the need for cooperation not only between the public and private sectors but also with social and environmental organizations, as well as all relevant stakeholders.

SE2 further emphasizes the value of collaboration, noting that stakeholders are encouraged to work closely together, leveraging their combined resources, expertise, and efforts to collectively address waste-related challenges. This collaborative approach not only aligns diverse interests but also facilitates the establishment of shared objectives and action plans to achieve a cleaner and more sustainable environment.

MUN2 highlighted the importance of trust in fostering cooperation among stakeholders: "*The collaborative efforts between the municipal body and other relevant entities are firmly rooted in a foundation of trust.*" This trust is the linchpin of collaboration among all parties, enabling open and effective communication between stakeholders, including residents, local organizations, and relevant authorities. Trust is established on the basis of transparency, effective communication, and the municipality's demonstrated commitment to responsible environmental stewardship.

4.4 Financial Consideration:

In this section, an exploration will be undertaken regarding the regulatory and policy framework that governs the waste sector in Lebanon. Additionally, an investigation will be conducted into the interconnection of financial considerations with operational challenges and policy matters.

4.4.1 Financial Impact:

A prominent challenge encountered across various sectors involved in waste management is a significant financial obstacle. This challenge arises from the considerable expenses associated with operating waste management facilities, including transportation and repair costs. The scarcity of readily available funds presents a formidable barrier to covering these expenditures. Consequently, securing the necessary funding to ensure the smooth operation and maintenance of these facilities becomes a critical concern, prompting the need to explore alternative funding sources and cost-cutting strategies.

It's crucial to highlight MUN1's observation that profits from recycled materials typically contribute to approximately 30% of the operational costs of such projects. However, this percentage varies depending on the season and time of year. This suggests that there remains a substantial 70% of costs that must be covered through other means of financing. Compounding

this issue is the fact that many municipalities find it challenging to meet these expenses, ultimately resulting in the closure of recycling facilities, as noted by NGO1.

Addressing these expenses necessitates securing financial support from the government or other sectors, such as environmental organizations. However, this endeavor presents a new set of challenges, as underscored by SF1: *"Obtaining financial backing for the project proves to be a formidable task, especially due to the absence of banks willing to offer loans for such initiatives. Furthermore, obtaining financial support from environmental associations demands substantial effort and isn't easily accessible, acting as a significant barrier to the recycling project's progress."*

It's essential to recognize that a substantial portion of loans and financial support from organizations is often directed toward assisting Syrian refugees in Lebanon. Many of these organizations prioritize refugee-related initiatives over addressing the waste situation. This dynamic further complicates the quest for support to implement an effective waste management plan.

Additionally, the inclusion of waste pickers in the waste management ecosystem has a dual impact. In this regard, MUN3 has articulated a compelling argument that highlights the substantial challenge posed by individuals who gather recyclable waste near containers and subsequently sell it. Their activity has led to the depletion of available recyclable waste in designated collection areas. This scarcity of recyclables has impeded the ability to generate revenue from selling these materials to offset the operational costs of the facility.

While waste pickers contribute to the reduction of litter on the streets and play a crucial role in diminishing the use of landfills, as illustrated in Figure 17, their activities also pose challenges to the financial sustainability of recycling programs by depleting available recyclable materials. This dual impact creates a nuanced situation where the positive influence of waste pickers on cleanliness

and waste reduction needs to be carefully balanced against their potential negative impact on recycling revenue.

To address this complex dynamic, it is proposed that waste pickers can become valuable contributors to reducing landfill waste if their activities are formalized through collaboration with landfill owners. By establishing formal agreements, landfill owners can provide training on health and safety, supply safety gear like boots and gloves, and regulate their access to active areas. This formalization not only enhances the overall efficiency of waste management but also ensures that the positive aspects of waste pickers' involvement are maximized while minimizing potential drawbacks to recycling programs.

MUN2 has offered a practical solution by suggesting a strategic adjustment in waste collection times to the evening. This approach minimizes opportunities for unauthorized scavenging and allows for the accumulation of a more substantial quantity of recyclable waste. Collecting waste in the evening makes it difficult for waste pickers to gather materials when law enforcement is active, serving as a deterrent to scavenging activities and contributing to a cleaner environment.

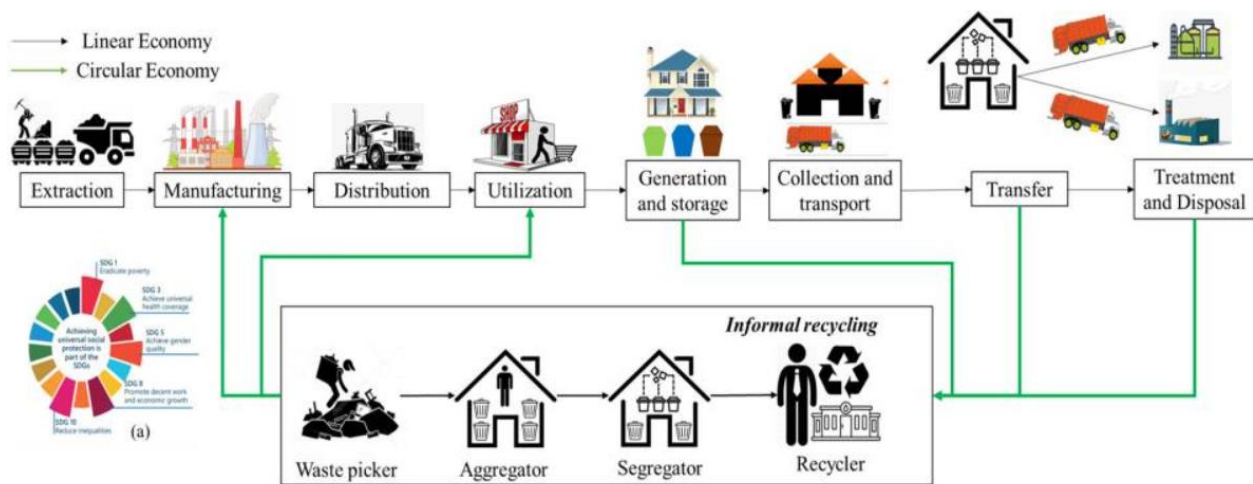


Figure 17: *The informal sector's contribution to shaping supply chain systems through the integration of circular economy principles (Sharma et al, 2021)*

4.4.2 Financial Resources:

While government sectors faced difficulties in securing financial support, private companies thrived and increased their profits by leveraging recyclables as a financial resource. As mentioned by SF1, private companies offered money to residents who submitted their waste as part of an exchange process. This system encouraged community involvement and enhanced residents' purchasing power. SF1 emphasized, "*Creating a system where recyclable materials hold monetary value incentivizes individuals to be more mindful of their consumption habits and waste disposal practices. The financial benefits can then be reinvested in the community, supporting local initiatives and individual needs.*" These evolving strategies employed aimed at creating a win-win scenario. Local residents stand to gain from the profits generated by these companies, which, in turn, reinvest in the local environment. Moreover, these private entities are actively engaging residents by informing them that a portion of their earnings goes toward donations to charitable organizations that support disabled individuals. This incentive encourages people to participate in charitable acts by segregating their waste. However, it's worth noting that NGO1 has expressed

reservations about this approach, stating concerns that offering money to individuals for segregating waste may not be a sustainable, long-term solution. NGO1 emphasized that the expenses associated with recycling could potentially surpass the profits from selling recyclables. NGO1 stated, "[...] *Encouraging citizens to sort waste in exchange for financial gain may lead to dependence, and if such support were to cease, it could result in people ceasing to segregate their waste.*"

In contrast, NGO2 proposes an alternative solution by recommending the imposition of additional costs on residents to cover operating expenses. This, according to NGO2, would create a vested interest for residents in the waste management process. In cases where residents opt not to participate, NGO2 suggests the implementation of additional taxes to manage the disposal of unsorted waste. The emphasis is placed on the outcome of a study conducted on the per-unit cost of waste treatment for households, revealing a modest fee of only \$2 per household. This amount is considered manageable for individuals.

4.5 Area of Improvement:

To comprehensively address Lebanon's waste management challenges and foster a sustainable system, a series of strategic measures should be taken. First and foremost, there is a consensus among experts, including RF1 and CF1, on the need to restructure governance with a focus on a circular approach. This approach involves aligning policies and practices with circular economy principles, as emphasized by RF1. A circular economy approach not only benefits the environment but also enhances the nation's well-being by reducing waste, creating economic opportunities, and improving resource efficiency.

Additionally, fostering collaboration between the public and private sectors, as advocated by CF1, can lead to a more efficient and sustainable waste management framework. CF1's suggestion was

"fostering collaboration between the public and private sectors. To ensure transparency and prevent any misuse, the public sector would continue to supervise the project." By adopting this approach, the financial burdens of addressing the waste crisis can be shifted away from the public sector, especially when its resources are limited, with the private sector assuming financial responsibility. Collaborative efforts between these sectors can leverage their respective strengths and expertise to create a more robust and sustainable waste management system.

Furthermore, clear legislation, along with the implementation of additional fees on citizens to cover operational costs, as suggested by SE1, is imperative to encourage greater participation in waste sorting. A comprehensive legislative framework can set the standards and expectations for waste management practices, while additional fees can be used to ensure that operational costs are covered. This financial incentive aligns with the idea that those who produce waste should share in the responsibility of its proper management.

In addition to these governance and financial aspects, the proposal put forth by SE1 and MUN1 advocates for the establishment of multiple recycling centers, waste sorting facilities, and sanitary landfills in each province as a means to reduce operational costs and promote responsible waste management. The strategic distribution of waste management infrastructure across the country can significantly enhance efficiency and accessibility for all residents, reducing the burden on any single area.

Moreover, MUN1 emphasizes the importance of regular assessments and adjustments to prevent overburdening, operational inefficiencies, and negative environmental impacts. This balanced approach to waste management takes into account available resources, waste generation rates, and technological capabilities, allowing for adaptability and continuous improvement in waste management practices.

Lastly, SE2 and NGO1 stress the significance of raising global awareness through extensive campaigns and media involvement to promote waste reduction, responsible management, and collaborative partnerships across various sectors. These efforts aim to ensure the active participation of all citizens in waste reduction, enhancing the overall effectiveness of waste management initiatives. Effective communication and awareness campaigns can inspire behavioral change and foster a sense of collective responsibility for waste management.

Incorporating these measures and strategies can pave the way for a more sustainable and effective waste management system in Lebanon, addressing environmental concerns, promoting economic opportunities, and ensuring the active engagement of all stakeholders.

4.6 Environmental Implications of Landfills in Lebanon

The aftermath of the 2015 crisis in Lebanon, marked by the closure of the Naameh landfill due to diverse environmental and public health concerns, led to the establishment of the Bourj Hammoud landfill as an essential interim solution to address ensuing waste management challenges. Strategically implemented to function temporarily, its primary objective was to mitigate immediate waste-related issues, acting as a practical stopgap measure while authorities worked towards formulating a sustainable, long-term waste management strategy.

Despite its strategic placement following the Naameh closure, the Bourj Hammoud landfill has introduced a suite of concerns primarily arising from its geographic proximity along the Mediterranean Sea (Figure 18). This location significantly amplifies the potential environmental impact of the landfill, necessitating heightened scrutiny and the implementation of targeted mitigation measures. While the landfill's construction adheres to meticulous standards, persistent concerns linger regarding its long-term viability, focusing on stability and the potential for enduring adverse environmental repercussions. Consequently, the landfill is poised to exert

harmful effects on the environment through the release of gases and the long-term probability of leachate introduction into the water, affecting both local human populations and the ecological diversity within the Mediterranean Sea.

Initial projections anticipated the Bourj Hammoud landfill would reach full capacity by 2019; however, unforeseen external influences disrupted this trajectory. The onset of the COVID-19 pandemic, coupled with concurrent economic crises in Lebanon, exerted a dual impact, resulting in a reduction in overall waste generation. However, this reduction proved insufficient, given the proximity of the landfill to residential areas where inhabitants reside approximately 500 meters away. This close proximity subjects them to both social and economic ramifications within the vicinity. Affluent individuals tend to avoid residing near landfills, while economically disadvantaged individuals may choose such locations due to lower housing rental costs. Consequently, this decision becomes a strategy employed by financially disadvantaged individuals to navigate economic constraints, yet it exposes them to potential long-term hazards, compromising both their health and safety due to the proximity to the landfill.



Figure 18: *The Bourj Hammoud's landfill near the Sea in the 2000s. (EJOLT, 2016)*

The existence of the Tripoli landfill similarly generates analogous consequences in its vicinity, given its adjacency to the Mediterranean Sea and the close proximity of residents (Figure 19). This spatial configuration exposes inhabitants to comparable long-term impacts. According to the UNDP report of 2017, the Tripoli landfill is associated with a substantial risk probability, denoted by a 40.7 risk sensitivity index. This index ranks notably higher than that of other landfills and dumpsites across Lebanon, raising significant apprehensions regarding potential leachate generation and its implications on groundwater quality.



Figure 19: A map showing the location of the Tripoli landfill (Moustafa et al, 2023)

The problem surpasses designated landfills; as numerous sites are employed for waste disposal without undergoing environmental assessments or regulatory oversight. This unregulated dumping exacerbates the harmful impact of waste on human life. In various regions of Lebanon, the lack of effective waste management is evident through the emergence of open dumping areas and unregulated burning sites. The deficiency in waste management strategies prompts individuals to opt for burning waste as a seemingly more convenient alternative to proper disposal. Consequently, this increases the risk of exposure to landfill gases and heightens the probability of landfill fires, which can have severe consequences on public health. In addition to that, open dumping and burning sites are prevalent in various countries, becoming particularly widespread in villages lacking recycling facilities. This haphazard disposal of waste poses environmental risks. When considering the situation in Lebanon, the nation's water resources play a crucial role in this

scenario. The geographical distribution of these water resources amplifies the issue, as many waste disposal sites are situated close to these vital water sources.

Figure 20 provides a visual representation of Lebanon's major water resources, strategically located across various regions. This dispersion raises concerns about the heightened probability of these vital water sources being situated near open dumping sites. Such geographical juxtaposition poses potential risks to water quality and ecosystem health, emphasizing the need for thoughtful waste management strategies to mitigate environmental impacts and safeguard Lebanon's essential water reservoirs.

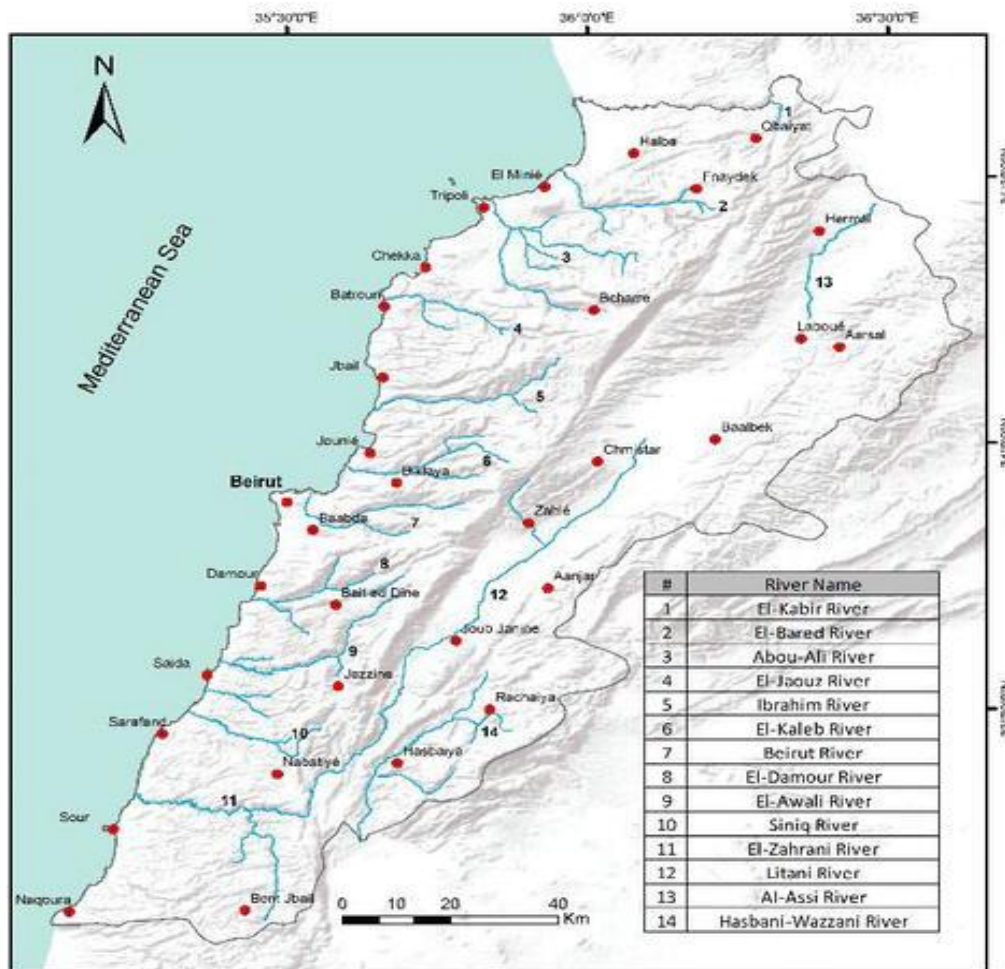


Figure 20: The primary water reservoirs in Lebanon (Shaban, 2021).

Chapter Five: Discussion & Recommendations

This chapter delves into the primary challenges underscored by the interviewees, previously analyzed in the preceding chapter. It further provides recommendations to enhance and overcome these challenges. The accompanying figure 21 visually illustrates the frequency with which interviewees emphasized specific challenges throughout their discussions.



Figure 21: *Frequency of Interviewee stating the challenges in their discussions*

5.1 A Model Focused on Household Participation

The Lebanese government stands at a critical juncture in redefining its waste management strategies, and a comprehensive approach is essential. A pivotal step involves actively endorsing recycling facilities and encouraging industries to prioritize recycled materials over new raw materials. To ensure the efficiency of waste management and foster a well-organized waste stream, initiating recycling at the household level is crucial.

Encouraging citizens to sort their recyclable waste at home into distinct bins is a practical and adaptable approach. This strategy has found success in various Lebanese cities, showcasing its

viability and offering a model for nationwide implementation. The engagement of citizens in source separation not only enhances waste management participation but also ensures the effective separation of recyclables at the very source.

Furthermore, implementing source separation practices can lead to a significant reduction in the frequency of waste collection cycles. This reduction not only streamlines the overall waste management system but also brings tangible economic benefits. By lowering transportation costs associated with waste movement, the government gains a financial opportunity. These cost savings can be reallocated to crucial areas, such as improving recycling facilities and technology. In essence, optimizing source separation and minimizing transportation costs provide the government with fiscal flexibility. This flexibility allows for strategic resource allocation, paving the way for investments in infrastructure and technology that contribute to a more sustainable and advanced waste management system.

The second crucial step in promoting community participation is comprehensive awareness. It is vital to inform the community about the separation process and the waste management plan. Educating citizens on active participation, clarifying their role in the plan's success, and providing a thorough understanding of their current position are foundational aspects.

To sustain and amplify this process, awareness campaigns in educational institutions become imperative. Schools, universities, and organizations play a fundamental role in disseminating knowledge, influencing individual lifestyles, and engaging the community in the separation process. Behavioral changes initiated within these institutions can act as catalysts for broader changes within households and communities.

Community involvement can be furthered by advocating for the use of reusable bags and introducing a small tax on plastic bags or disposable plastic items. This economic incentive

encourages individuals to opt for sustainable alternatives, fostering responsible waste management practices. A comparable strategy can be applied to plastic bottles by incorporating a nominal deposit fee, thereby reducing single-use plastic consumption and promoting a more sustainable approach to packaging.

5.2 Reevaluation and Implementation of Policies and Regulations

Effectively managing waste in Lebanon demands more than just individual efforts at the household level; it requires a comprehensive governance strategy that integrates environmental protection, governmental cost management, socio-economic impact optimization, and implementation simplicity. This multifaceted approach encompasses distinct layers of governance (Figure 22). It initiates policy formulation entrusted to global environmental regulators, wherein broad waste-related policies, key performance indicators, and targets are set (Arthur, 2018). The subsequent phase involves translating these policies into specific regulations and delineating operational restrictions for waste operators and stakeholders (Arthur, 2018). Ensuring compliance becomes paramount, with enforcement mechanisms playing a crucial role in achieving this objective. This multifaceted approach can be understood through the lens of transition theory, which emphasizes the need for systemic change and governance structures that facilitate a transition to more sustainable practices.

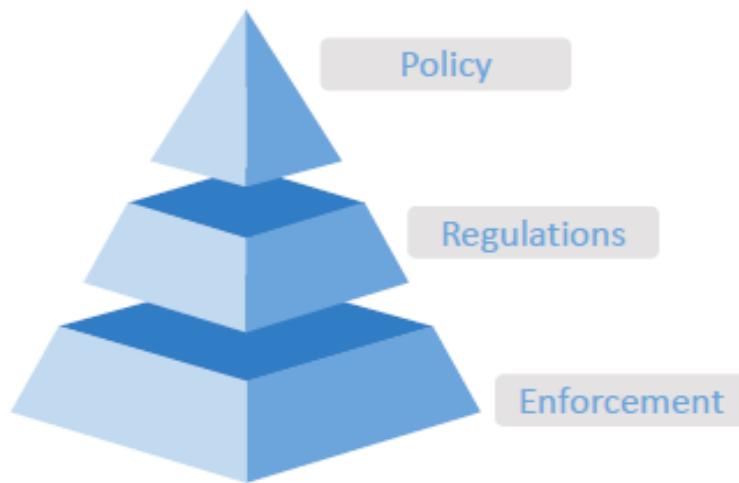


Figure 22: *Layers of governance (Arthur, 2018)*

In the context of Lebanon, the governance framework involves distinct layers, starting with global environmental regulators setting broad waste-related policies, key performance indicators, and targets. However, the transition from theory to execution faces significant challenges. Despite ongoing discussions about new regulations within the ministry, the persistence of unchanged policies over an extended period hampers effective governance. Practical implementation encounters obstacles ranging from logistical issues to resistance and a lack of clarity among policy implementers.

Transition theory suggests that effective governance requires adapting policies to changing circumstances. Lebanon's unique political and geographical landscape adds layers of complexity to implementing new strategies. Political considerations and regional variations impact the effective execution of policies on the ground. Effectively addressing challenges in the Lebanese governance system involves not only updating policies but also navigating the intricate interplay of political dynamics and geographical factors. Achieving efficient implementation necessitates a

comprehensive understanding of these challenges and a strategic approach considering the broader context in which these policies are enacted.

A crucial aspect of governance in waste management involves combating unauthorized landfills and open dumping. A proactive measure to combat illegal dumping effectively involves deploying collection trucks equipped with global positioning system (GPS) technology. The dual purpose of these GPS-enabled trucks includes real-time tracking of waste disposal, and providing precise data on deposit locations for monitoring and enforcement. This information is invaluable for the swift identification and resolution of instances of unauthorized dumping. Additionally, the data collected by GPS-equipped trucks can be leveraged to enhance overall waste management processes, offering insights into waste generation patterns. This, in turn, supports informed decision-making, leading to more efficient resource allocation, improved route planning for collection, and strategic adjustments to waste management strategies based on observed trends.

Another critical government intervention entails establishing a comprehensive database to ensure transparency and build trust among stakeholders. A centralized database is essential for motivating and engaging communities, providing real-time data that accurately reflects the current waste crisis. Clear regulations should mandate that every company, whether private or public, shares its data on a common platform accessible to the public. This not only promotes transparency but also empowers communities by providing valuable information on the prevailing state of the waste challenge. Enforcing transparency and mandating data sharing allows municipalities to collaborate with private sectors and form partnerships among neighboring municipalities to address the waste problem collectively. Access to real-time data allows municipalities to observe the outcomes of recycling and reusing efforts in other regions, encouraging cooperative efforts. This collaboration not only reduces operational costs but also contributes to minimizing environmental impact,

aligning with the earlier-mentioned objectives. The shared data acts as a catalyst for informed decision-making and collective efforts toward more sustainable waste management practices.

5.3 Financial instruments to a recovery-cost mechanism

Over the last two years, Lebanon has faced escalating financial challenges, primarily stemming from the compounding impacts of inflation and economic crises, as previously mentioned. To effectively navigate and overcome these challenges, the Lebanese waste management system must strategically implement various financial instruments. These instruments are indispensable for recuperating essential costs and facilitating the operational expenses associated with the effective management of recycling and reusing facilities.

A critical component of this strategic approach involves the utilization of financial incentives. These incentives manifest in diverse forms, encompassing deposit-refund systems, as detailed in the preceding section (5.1). Additionally, financial grants, tax cuts, and discounts, as highlighted by Arthur in 2018, constitute integral elements of the financial incentive structure. For instance, financial grants can be allocated to support the establishment and expansion of recycling facilities, while tax cuts and discounts can serve as incentives for businesses and industries to adopt more sustainable waste management practices.

The integration of these varied financial measures holds the potential to fortify the financial resilience of Lebanon's waste management system, simultaneously contributing to environmental sustainability. Furthermore, these initiatives can foster collaboration between the public and private sectors, encouraging heightened participation in waste reduction efforts. This holistic approach not only addresses immediate financial challenges but also establishes a foundational framework for a more sustainable and efficient waste management ecosystem in the long term.

Another crucial approach that warrants increased attention is the implementation of a cost recovery mechanism. This mechanism is instrumental in covering the expenses required to implement a sustainable waste management plan and to facilitate the operation of recycling facilities. The cost recovery mechanism can be achieved through strategic investments in the recycling industry. The government can play a pivotal role in this by investing in the sector, thereby generating revenue from the sale of materials that can be recycled.

By investing in recycling, significant progress can be made in reducing the overall costs associated with mitigating the damage caused by landfills and open dumping. Additionally, it establishes a framework where the financial burden is partially offset by the revenue generated through the sale of recycled materials.

To enhance this mechanism, it is essential to establish regulations that require residents capable of generating more waste than estimated to bear the cost of waste disposal and recycling services. Several European countries have successfully implemented a strategy where the expense of waste disposal is linked to the volume of waste produced. In essence, the greater the amount of waste generated, the higher the cost associated with managing the recycling process. This principle can also be applied when residents dispose of their waste into bins, where the fee they incur depends on the size of the bin. Moreover, different prices should be set based on the type of waste, taking into account factors such as the nature of the waste material.

For instance, disposing of furniture incurs higher costs due to the complexities in managing and transporting such items to sorting facilities. On the other hand, waste materials like papers or cartons result in lower fees, as the compacting vehicles used for their collection require less space and entail reduced transportation costs. This approach not only establishes a financial incentive for

waste reduction but also contributes to minimizing the environmental impact of waste by discouraging excessive generation.

5.4 A Sustainable Approach to Landfill Management

The geographical placement of landfills along the coastline poses a significant risk to Lebanese safety measures due to potential instability and adverse ecological effects. The specific locations of Bourj Hammoud and Tripoli landfills warrant focused attention to mitigate these concerns.

To effectively address the challenges posed by landfills, particularly those in Bourj Hammoud and Tripoli, a comprehensive solution necessitates a structured approach. The initial step involves enhancing the design and monitoring of these specific landfills to mitigate safety and ecological impacts. This improvement process requires a meticulous examination that systematically incorporates considerations for potential environmental consequences. Conducting a thorough review is imperative to identify and address potential hazards and risks associated with landfill placement and operation. Additionally, integrating advanced leachate and gas extraction technology is crucial to prevent adverse impacts on the surrounding environment. While Bourj Hammoud landfills currently employ leachate extraction technology, regular assessments of its functionality would enhance its effectiveness.

Furthermore, the implementation of robust monitoring systems plays a pivotal role in managing landfill stability and environmental indicators. These systems should be meticulously designed to provide real-time data on landfill conditions, facilitating the timely detection of any deviations from safety and environmental standards. Regular inspections and assessments are essential to continually evaluate the stability of the landfills. This proactive approach focuses on preventing adverse impacts on the surrounding ecosystem and safeguarding the health of nearby communities.

Moreover, it is imperative to proactively consider alternatives to the existing landfills to prevent exceeding their operational lifespan and reaching maximum capacity, which could elevate the risk of adverse effects on the sea and the surrounding area. A prudent strategy involves exploring recycling and reusing materials as a viable alternative. Establishing recycling facilities at a considerable distance from residential areas is essential to mitigate any potential negative impacts on residents. By incorporating recycling and reuse practices, the need for excessive landfill usage can be reduced, contributing to sustainability and minimizing environmental risks. Identifying suitable locations for recycling facilities away from densely populated areas ensures that the processes do not adversely affect the well-being of nearby communities.

Chapter Six: Reflection and Conclusion

This chapter addresses the study's limitations, provides reflections, and presents an overall conclusion for the thesis. It concludes with suggestions for future research.

6.1 Conclusion

This study underscores a significant environmental challenge in Lebanon arising from the escalating waste generation. Unfortunately, there has been a notable lack of proactive measures to address this issue, resulting in waste disposal in landfills and triggering various social, economic, and environmental repercussions in the surrounding areas. It is vital to promptly address and mitigate this problem, with the urgency underscored by the recognition that delays could lead to more extensive challenges in the future.

Taking action is crucial for efficiently resolving the current situation and as a proactive measure to prevent the worsening of issues if neglected. The timing of the action taken plays a crucial role in the solutions' effectiveness. In essence, decisive action is crucial for minimizing long-term consequences and establishing a sustainable approach to waste management in Lebanon.

To comprehensively explore the landscape of waste management in Lebanon and formulate effective recommendations for enhancing sustainability, the central research question guiding this thesis is as follows: "***What are the key challenges hindering the efficient implementation of a sustainable waste management plan designed to reduce solid waste in landfills and mitigate associated environmental and socio-economic consequences?***"

To address the overarching research question, the thesis is structured around four distinct sub-questions. The first sub-question investigates ***the impact of landfills on the natural environment, specifically focusing on surface and groundwater sources, air and soil quality, noise pollution, and windblown litter***. Chapter two is dedicated to exploring the answer to this sub-question,

utilizing secondary research methods to gather information. The literature review in this chapter emphasizes the detrimental effects of landfills on the surrounding environment, highlighting various aspects, particularly their implications for human life and the broader ecosystem. It reveals that landfill gas emissions pose environmental risks due to the release of hazardous gases like methane and carbon dioxide. The composition of emitted gases varies based on waste factors, with methane being notably more harmful than CO₂.

Landfills not only present environmental threats but also give rise to socio-economic challenges, prompting the formulation of sub-question two: "***What socio-economic consequences arise from the presence of landfills in the surrounding areas?***" Exposure to landfill gas and the consumption of water contaminated by landfill leachate result in public health issues, with adverse effects on congenital health, birth outcomes, and an increased risk of cancers (Lioy, 1990; Adami et al., 2001; Danthurebandara et al., 2012). Landfills also affect land value, land degradation, and land availability, with proximity negatively impacting property values, reducing tax revenues for local services, and deterring investment in the area (Reichert et al., 1992; Danthurebandara et al., 2012; National Research Council, 2000).

The third sub-question, "***What are the primary challenges encountered by both the public and private sectors, as well as individual initiatives, in the implementation of waste management practices, and how do these challenges impact the effectiveness of waste management systems?***" has been addressed in chapter four, which delves into the results of the interviews conducted to gather information. Across all sectors—public, private, and organizational—the predominant challenges include funding and financial constraints, as well as logistical and transportation issues exacerbated by the current Lebanese situation. Additionally, policy and regulation present barriers, as they do not directly support recycling facilities, and there is consistently a lack of data and

information, which further impedes the planning of a sustainable waste management system in Lebanon.

The last two sub-questions, *"What strategies can be implemented to encourage the adoption of waste management practices at the individual level?"* & *"How can systemic-level strategies be devised and implemented to promote the widespread adoption of effective waste management practices?"* is thoroughly discussed and answered in chapter five, offering recommendations for implementation in the Lebanese system to decrease waste generation and reduce the reliance on landfills and open dumping. The chapter emphasizes the importance of sharing information with households to increase their participation in the waste management process, thereby enhancing efficiency in waste sorting. Furthermore, altering policies and regulations is suggested to boost involvement in recycling and reusing processes, leading to a decrease in waste generation. Additionally, to cover the financial costs of operating and implementing the waste management strategy, it is deemed essential to introduce financial incentives. Such incentives could take various forms, including tax breaks, subsidies, or reward systems, designed to motivate individuals and businesses to adopt sustainable waste management practices. Another crucial approach that warrants increased attention is the implementation of a cost recovery mechanism. This mechanism plays a pivotal role in meeting the financial requirements for executing a sustainable waste management plan and ensuring the smooth operation of recycling facilities. Achieving effective cost recovery involves strategic investments in the recycling industry.

6.2 Reflections and Limitations

This research sheds light on critical aspects of some of the challenges experienced in the waste management sector in Lebanon. However, it is important to acknowledge certain limitations that may impact the generalizability and depth of the findings. Firstly, the study relies primarily on

secondary research methods, offering a comprehensive overview of existing literature but potentially missing the dynamic nature of on-the-ground situations. The scope is confined to the current state of waste management in Lebanon, lacking full consideration of potential changes or developments in the future.

Second, the interview-based data collection, though informative, introduces limitations tied to the subjective nature of responses. Bias or interpretation variations among interviewees may influence the understanding of challenges. Reflecting on the research process emphasizes the need for a holistic, interdisciplinary approach due to the interconnected nature of environmental, social, economic, and policy aspects.

Moreover, it is also crucial to acknowledge the geographical scope of the interview-based data collection, which was predominantly focused on the southern part of Lebanon. This geographical limitation poses a constraint on the generalizability of findings and highlights the need for broader regional representation. In future research endeavors, it is imperative to consider expanding the scope to include the northern part of Lebanon. This expansion would contribute to a more inclusive and representative study, capturing a diverse range of perspectives and experiences related to waste management challenges across different regions of the country. This would provide a real-time understanding of the challenges and opportunities faced by various stakeholders in waste management in Lebanon. Exploring the potential impact of technological innovations and advancements in waste management practices could be a promising avenue for future research. Investigating how emerging technologies, such as smart waste management systems or innovative recycling methods, can be integrated into existing frameworks could contribute to the development of more efficient and sustainable waste management strategies.

Additionally, a comparative analysis of waste management practices across different countries with similar challenges could offer valuable insights and lessons for Lebanon. Understanding successful models implemented elsewhere and adapting them to the Lebanese context could provide practical solutions for overcoming specific challenges identified in this research.

In conclusion, while this thesis provides limited insight into some of the challenges of the waste management sector in Lebanon, continuous research and collaborative efforts are essential to navigate the evolving nature of environmental challenges and work towards sustainable solutions.

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Appendix A: Interview Questionnaire (English Version)

► Introducing my self and my research objective:

Hello,

I am a master's student in Environmental and Infrastructure Planning at the University of Groningen in the Netherlands. Due to the environmental issues facing Lebanon, particularly in waste management and the presence of open dumps in cities and villages, my study aims to reduce the use of open dumps and utilize the principles of the circular economy to benefit from waste and minimize its volume.

Therefore, I kindly request your participation in in this interview and sharing your experiences and observations to benefit from them in my research.

Please note that your identity will remain anonymous, and all the information provided will be kept confidential, used solely for scientific purposes.

There are no risks associated with this research study. No information will be disclosed that could identify any participant. Additionally, the information will only be used for research purposes.

Participation in this study is entirely voluntary, and you can stop this interview at any time!

Thank you for your cooperation.

1- Kindly brief us regarding your role and experience working within Waste Management System in your town.

2- What lead to the decision to start working on Waste Management in your town? & What was it's objective?

3- In your opinion, was this initiative successful? Please consider the following criteria when providing your response:

- *Achievement of Objectives: To what extent did the initiative accomplish its intended goals and objectives?*
- *Community Engagement: Evaluate the level of involvement and support from the community or relevant stakeholders.*

- *Sustainability: How likely is the initiative to be sustained in the long term and have a lasting impact?*
- *Cost-Effectiveness: Consider whether the initiative's benefits outweigh the resources and efforts invested.*
- *Environmental Considerations: Examine the impact of the initiative on the environment and ecological balance.*
- *Challenges Faced: Reflect on the obstacles or challenges encountered during the initiative's implementation.*

4- Can you provide more information about the physical aspects of solid waste management in your town, such as the methods of collection, processing, recycling, and disposal?

5- Is there any sorting taking place at the source? If yes, could you provide further details? Are the residents willing to participate?

6- Could you please inform me if the activities I am about to mention were challenges that could have impacted your project's objectives? If so, please elaborate on the challenges you faced in relation to those activities.

	Check
Planning Integrated Waste Manageme	<input type="checkbox"/>
Engaging with the Municipal Council	<input type="checkbox"/>
Awareness raising & Capacity Building of Youths	<input type="checkbox"/>
Procuring bins and distribution	<input type="checkbox"/>
Building and operating the facility	<input type="checkbox"/>
Staffing the Facility	<input type="checkbox"/>
Selling recyclables	<input type="checkbox"/>
Generating revenues	<input type="checkbox"/>

7- Now, I would like to delve into additional challenges from different categories than those mentioned earlier. Could you please share whether you have encountered any of the following challenges in the context of the Integrated Waste Management project? Additionally, kindly elaborate in detail on each challenge and describe how you successfully managed it. Moreover, please inform me if there are any additional challenges that we have not discussed yet, which posed challenges for your project and its operations.

- Public Resistance and Perception
- Funding and Financial Constraints
- Policy and Regulatory Barriers
- Lack of Data and Information
- Infrastructure and Technology Limitations
- Community Participation and Cooperation
- Logistics and Transportation
- Health and Safety Concerns
- Waste Segregation and Contamination
- Other...

8- What are the major Strength that this initiative has?

9- What are the major weaknesses that this initiative has?

10- What are the major threats that this initiative has?

11- Having been into this experience, what further steps must be taken for this initiative to leave a bigger impact? (Key Lessons).

12- Household waste composition and generation data provide valuable information for waste management strategies. Do you possess data regarding waste composition/generation at the household level?

Now talking about Lebanon:

13- Could you provide your perspective on solid waste management at a national scale? What are the advantages and disadvantages/limitations of the current system?

14- Can you describe any successful waste management initiatives or projects that have been implemented in Lebanon, and what were the key factors that contributed to their success?

15- How can policy and regulation be strengthened to support sustainable waste management practices in Lebanon, and what specific measures do you think should be implemented?

16- How do you think Lebanon's current waste management system can be improved to address challenges?

17- Closing Notes

Appendix B: Interview Questionnaire (Arabic Version)

◀ التعريف بنفسي وهدفى البحثي:

مرحباً،

أنا طالب ماجستير في التخطيط البيئي والبنية التحتية في جامعة جرونينجن في هولندا. نظراً للمشاكل البيئية التي يواجهها لبنان، لا سيما في مجال إدارة النفايات ووجود المكبات المفتوحة في المدن والقرى، تهدف دراستي إلى تقليل استخدام المكبات المكشوفة والاستفادة من مبادئ الاقتصاد الدائري للاستفادة من النفايات وتقليل حجمها.

لذا أرجو منكم المشاركة في هذه المقابلة ومشاركة تجاربكم وملاحظاتكم للاستفادة منها في بحثي.

يرجى ملاحظة أن هويتك ستبقى مجهولة، وجميع المعلومات المقدمة ستظل سرية، وتستخدم فقط للأغراض العلمية.

لا توجد مخاطر مرتبطة بهذه الدراسة البحثية. لن يتم الكشف عن أي معلومات يمكن أن تحدد هوية أي مشارك. بالإضافة إلى ذلك، سيتم استخدام المعلومات فقط لأغراض البحث.

المشاركة في هذه الدراسة تطوعية تمامًا، ويمكنك إيقاف هذه المقابلة في أي وقت!

شكراً لتعاونكم.

1- يرجى إطلاعنا على دورك وخبرتك في العمل ضمن نظام إدارة النفايات في مدينتك.

2- ما الذي دفعك إلى اتخاذ قرار البدء بالعمل على إدارة النفايات في مدينتك؟ وماذا كان هدفها؟

3- برأيك هل كانت هذه المبادرة ناجحة؟ يرجى مراعاة المعايير التالية عند تقديم إجابتك:

• تحقيق الأهداف: إلى أي مدى حققت المبادرة أهدافها وغاياتها المنشودة؟

• مشاركة المجتمع: تقييم مستوى المشاركة والدعم من المجتمع أو أصحاب المصلحة المعنيين.

• الاستدامة: ما مدى احتمالية استمرار المبادرة على المدى الطويل وأن يكون لها تأثير دائم؟

• فعالية التكلفة: فكر فيما إذا كانت فوائد المبادرة تفوق الموارد والجهود المستثمرة.

• الاعتبارات البيئية: دراسة تأثير المبادرة على البيئة والتوازن البيئي.

• التحديات التي تمت مواجهتها: التفكير في العقبات أو التحديات التي تمت مواجهتها أثناء تنفيذ المبادرة.

4- هل يمكنك تقديم المزيد من المعلومات حول الجوانب المادية لإدارة النفايات الصلبة في بلدتك، مثل طرق الجمع والمعالجة وإعادة التدوير والتخلص منها؟

5- هل يتم الفرز من المصدر؟ إذا كانت الإجابة بنعم، هل يمكنك تقديم المزيد من التفاصيل؟ هل السكان مستعدون للمشاركة؟

6- هل يمكنك إبلاغي إذا كانت الأنشطة التي سأذكرها تمثل تحديات قد تؤثر على أهداف مشروعك؟ إذا كان الأمر كذلك، يرجى توضيح التحديات التي واجهتها فيما يتعلق بهذه الأنشطة.

- التخطيط للإدارة المتكاملة للنفايات
- التعامل مع المجلس البلدي
- رفع الوعي وبناء قدرات الشباب
- شراء الصناديق وتوزيعها
- بناء وتشغيل المنشأة
- التوظيف في المنشأة
- بيع المواد القابلة لإعادة التدوير
- توليد الإيرادات

7- الآن، أود الخوض في تحديات إضافية من فئات مختلفة عن تلك المذكورة سابقًا. هل يمكنك مشاركة ما إذا كنت قد واجهت أيًا من التحديات التالية في سياق مشروع الإدارة المتكاملة للنفايات؟ بالإضافة إلى ذلك، يرجى تقديم تفاصيل عن كل تحدٍ ووصف كيف تمكنت من إدارته بنجاح. علاوة على ذلك، يرجى إبلاغي إذا كانت هناك أي تحديات إضافية لم نناقشها بعد، والتي تشكل تحديات لمشروعك وعملياته.

- المقاومة العامة والإدراك
- التمويل والقيود المالية
- العوائق السياسية والتنظيمية
- نقص البيانات والمعلومات
- قيود البنية التحتية والتكنولوجيا
- المشاركة والتعاون المجتمعي
- الخدمات اللوجستية والنقل
- مخاوف الصحة والسلامة
- فصل النفايات والتلوث
- آخر...

8- ما هي أهم نقاط القوة التي تمتلكها هذه المبادرة؟

9- ما هي أبرز نقاط الضعف التي تعاني منها هذه المبادرة؟

10- ما هي أبرز التهديدات التي تواجهها هذه المبادرة؟

11- بعد أن مررت بهذه التجربة، ما هي الخطوات الإضافية التي يجب اتخاذها حتى تترك هذه المبادرة تأثيرًا أكبر؟ (الدروس الرئيسية).

12 -توفر بيانات تكوين النفايات المنزلية وتوليدها معلومات قيمة لاستراتيجيات إدارة النفايات. هل تمتلك بيانات تتعلق بتكوين/توليد النفايات على مستوى الأسرة؟

نتحدث الآن عن لبنان:

13 -هل يمكنك تقديم وجهة نظرك حول إدارة النفايات الصلبة على المستوى الوطني؟ ما هي مزايا وعيوب/حدود النظام الحالي؟

14 -هل يمكنك وصف أي مبادرات أو مشاريع ناجحة لإدارة النفايات تم تنفيذها في لبنان، وما هي العوامل الأساسية التي ساهمت في نجاحها؟

15 -كيف يمكن تعزيز السياسات والتنظيم لدعم ممارسات الإدارة المستدامة للنفايات في لبنان، وما هي التدابير المحددة التي تعتقد أنه ينبغي تنفيذها؟

16 -كيف تعتقد أنه يمكن تحسين نظام إدارة النفايات الحالي في لبنان لمواجهة التحديات؟

17- ملاحظات ختامية