

IMPACT OF NATIONAL AND MUNICIPAL ENVIRONMENTAL STANDARDS ON THE
DEVELOPMENT OF EFFECTIVE SOLID WASTE MANAGEMENT SYSTEMS IN
JEDDAH, KINGDOM OF SAUDI ARABIA

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Abstract

The following research paper analyzes the impact of national and municipal environmental standards on the development of effective Solid waste management systems in Jeddah, Kingdom of Saudi Arabia. The research is essential in ensuring that there are notable positive changes in the disposal of solid waste by both the local government and the national government of the Kingdom of Saudi Arabia. The following paper follows a strategic plan and procedure in ensuring achievement of the goal and purpose of the research. The approach used in this paper is a comparison of the current local system and a proposed improvement of some of the legal laws surrounding Saudi Arabia's environmental laws and regulations and the implementation of these laws in both the country's local and national governments. The research relies on data collected from the legal documents and policies on waste by Jeddah's city and government management authority. The findings reveal the origin and impact of solid wastes in the Kingdom of Saudi Arabia, the environmental laws surrounding the disposal of waste, the challenges faced in the disposal of waste, and some of the changes and adjustments that the legal system in the country can put in place to ensure protection of environment. Some of these challenges include the negative effect of urbanization and the threat it posed in the collection of data and lack of proper coordination between both local and national government proved a challenge in ensuring provision of proper information. The conclusion reached in this paper is that Jeddah city lacks proper coordination from both the national government and local government in ensuring proper disposal of waste. Therefore, new laws distinguishing roles and responsibilities between both local and national governments are required.

1. INTRODUCTION

1.1. Background to Waste Management's Problems in the Kingdom of Saudi Arabia (KSA)

Solid waste encompasses a wide range of materials generated from animal and human activities that are discarded as unwanted and useless and that are a product of industrial, residential, and commercial activities in rural and urban areas. Solid waste has been described as the unwanted substances that cannot be used economically. It has been argued that the waste is derived from human activities and if it is not treated it leads to pollution of the air, water and soil.¹ The problem of waste is even more prevalent in densely populated areas such as cities and urban centers.² Since emerging economies such as Saudi Arabia are also experiencing rapid urbanization, it becomes even more difficult to address the ever-increasing amounts of wastes generated in the cities. Government authorities tasked with waste collection, treatment, and disposal struggle with waste management as both financial and technical resources constrain them. In cities and urban areas, solid waste mostly is the product of industrial, residential, and commercial activities.³ Solid waste management consists of collection and treatment of solid wastes, as well as offering solutions to recyclable and compostable waste. Contemporary solid

¹ Chadar, S. N., and K. Chadar. "Solid waste pollution: A hazard to environment." *Recent Advances in Petrochemical Science* 2, no. 3 (2017): 41-43.

² Shahzad, K., et al. "Biodiesel production potential from fat fraction of municipal waste in Makkah." *PLoS One*, 12, no. 2, (2017), 4

³ Khalid A. Alkhuzai, *Use of Life Cycle Assessment (LCA) to Develop a Waste Management System for Makkah, Saudi Arabia* (2014), 16

waste management emphasizes changing solid waste into valuable resources.⁴ Therefore, proper solid waste management is a multifaceted activity that involves the investment of resources, committed leadership, and the effective enforcement of environmental standards. This research explores the impact of national and municipal environmental standards on the development of effective solid waste management systems in Jeddah, Kingdom of Saudi Arabia. It explores this impact by answering these research questions

1. How does the current environmental legal framework in KSA impact the effectiveness of solid waste management strategies in Jeddah, KSA?
2. What kinds of policies could help to achieve sustainable solid waste management practices in Jeddah, KSA?

The city of Jeddah located in the Hejaz region on the west coast is the commercial center of the Kingdom of Saudi Arabia (KSA). Jeddah, with a population of more than 4 million people, is the largest city in Makkah Province and the second-largest in Saudi Arabia after capital Riyadh.⁵ Jeddah is the second-largest and second-busiest seaport in the entire Arab world and the main gateway to the holy city of Mecca. Islam's second holiest city, Medina is located 360 kilometers north of Jeddah. In the last couple of decades, Jeddah has faced significant urban development as a result of new capital investments and its competitive edge in science and engineering in KSA.⁶ According to the 2009 Innovation Cities Index, Jeddah was ranked the fourth most innovative city in Africa and the Middle East.⁷ The proximity of the city to the Red

⁴ Reddy, P. J. *Municipal Solid Waste Management: Processing - Energy Recovery - Global Examples*. Boca Raton: CRC P, 2011, 55

⁵ Bosworth, Clifford E. *Historic Cities of the Islamic World*. Leiden: BRILL, 2007, 9

⁶ McFee, James. *City Maps Jeddah Saudi Arabia*. Soffer Publishing, 2017, 15

⁷ McFee, 19

Sea makes fishing and seafood trading and important consumption component of Jeddah culture. Due to massive industrialization and urbanization, Jeddah's solid waste has increased significantly as it now produces more than 4.5 million tons of it every year.⁸ Studies show that population pressure is adversely affecting the effectiveness of the current solid waste management system.⁹ For instance, Jeddah's landfills are on the brink of filling up.

Environmental standards refer to administrative regulations or civil law rules, which are implemented to treat and maintain the environment. The Kingdom of Saudi Arabia's environmental protection laws fall under Article 32 of the Basic Law of Governance which specifically states that "The State shall work towards the preservation, protection, and improvement of the environment, as well as prevent pollution."¹⁰ Environmental standards are often set by the government and consist of bans on specific activities, empowerment of certain authorities and permitting the use of land or water for a specific activity. Environmental standards often differ depending on the type of economic or human activity. Effective environmental standards produce quantifiable and enforceable laws or regulations that promote environmental conservation and sustainable use of resources.¹¹ In the Kingdom of Saudi Arabia (KSA), the national and municipal authorities implement various environmental regulations that aim to establish and develop effective solid waste management systems for its cities. This research examines how these national and municipal standards are geared towards the establishment of effective solid waste management systems that work and that will keep enforcing the preservation, protection, and improvement of the environment in addition to

⁸ Saudi Gazette Report, 18

⁹ Bosworth, 16

¹⁰ Saudi Government, 2020

¹¹ Hosetti, 56

preventing pollution in Jeddah, KSA. To achieve this research goal, the researcher recognizes that addressing solid waste management problems in cities goes beyond having good legislation and environmental standards. There should be an effective enforcement strategy targeting every type of wastes i.e. solid waste.

1.1.1 Roadmap

Part 1 introduces the basic information about the waste management and the fact that there are potential waste management problems affecting Jeddah's residents, companies and authorities, thereby calling for the enforcement of new approaches to the current laws and regulations regarding environmental protection, with a focus in waste management.

1.1.2 Types of Solid Wastes

Municipal solid waste includes household waste, sanitation residue, waste from the streets, and construction and demolition debris. The garbage comes from residential and commercial complexes. With the rise in urbanization and changes in lifestyles and food habits, the amount of solid waste generated has increased rapidly in the last two decades in KSA. Solid wastes can be divided into four broad categories, i.e. organic, toxic, recyclable and soiled.¹² First, organic wastes include kitchen waste, vegetables, flowers, leaves and fruits. Second, toxic wastes consist of old medicines, paints, chemicals, bulbs, spray cans, shoe polish, pesticide, and fertilizer containers, and so on. Third, recyclable wastes include paper, metals, glass and plastics. Finally, soiled wastes include hospital wastes such as clothing that has been soiled by blood and

¹² Chandrappa, Ramesha, and Diganta B. Das. *Solid Waste Management: Principles and Practice*. Berlin: Springer Science & Business Media, 2012, 23

body fluids. In KSA, almost 30 percent of the total solid waste generated remains uncollected, while cities such as Jeddah are ill-equipped to transport the wastes into the landfills properly.¹³

In the last two decades, the consumer market in KSA has considerably grown. This growth has been accompanied by the emergence of several products packed in cans, plastics, aluminum foils and other non-biodegradable items. These products can cause significantly huge harm to the environment if not managed appropriately. Though in some parts of the world plastics have been banned, KSA still lags in the development of legislation and standards related to plastic use and disposal.¹⁴ This causes a lot of harm to KSA's environment, especially because the cities in the kingdom are vulnerable to harms from environmental damage and pollution. Solid waste harms people's and animals' health while it causes damage to the surrounding environment. If and when the relevant authorities in Jeddah fail to properly manage the solid waste, such that there's solid waste from around the city, they can be faced with serious health hazards, in addition to infectious diseases. The lack of proper solid waste disposal leaves solid waste lying around, and this is dangerous for pre-school children in the city. The waste may also harm waste-workers because they are continually exposed to toxic, infectious material. Those who live near any dumpsites in the city are considered high risk groups too. There's the likelihood that solid waste, being so toxic, and possessing qualities for containing varieties of pathogenic microorganisms than sewage sludge, can cause serious public health problems, some related to land, and the rest to water and air pollution.¹⁵ More harm even arises when the solid

¹³ Khalid A. Alkhuzai, 37

¹⁴ Khalid A. Alkhuzai, 43

¹⁵ Hakami and Seif, 6

waste is dumped in a manner that creates landfills, which also expose the residents to further health problems.

In the last decade, there has been a rise in the pollution of the groundwater in and around Jeddah. Towards the east of Jeddah is Wadi Bani Malik, an area as large as 159 square kilometers, most of which are alluvial and which makes the region an alluvial aquifer. On the upper part of Wadi Bani Malik is Al Musk Lake, which has formed as a dumpster area for the sewage that comes from tankers from Jeddah and the regions surrounding it. The on-site disposal of sewage has led to the problem of solid waste growing around the lake and Wadi Bani Malik, and this waste has to be handled by the city's and the region's governments to avoid it causing further pollution of groundwater and soil, which would increase the possibility that the whole region exposes Jeddah's residents to the dump which attracts disease-causing organisms. More pollution of this region can also lead to air contamination which is bad for the arid surroundings and in effect Jeddah's residents. When the tankers take their dump to Wadi Bani Malik and Al Musk Lake, they subject the area to increasing concentrations of sulfur, boron from human waste, among other toxic elements like lithium, barium, and arsenic. These are problematic chemicals even to solid waste management by the city's waste management authorities because they cause long-term effects on their health and on the health of almost everyone who uses the groundwater from the basin.¹⁶ On the positive note, some retailers in the country have begun to pack items in reusable and biodegradable bags. These bags can be easily composted or reused. Studies showed that proper handling of biodegradable wastes considerably reduces the solid waste burden that cities have to tackle.¹⁷

¹⁶ Rehman et al, 359

¹⁷ Khalid A. Alkhezai, 59

1.1.3 Solid Waste Management Problem

Solid waste management involves the incurrence of significant economic, social, political, environmental, and technological costs and resources.¹⁸ In the case of emerging economies, the situation is even worse as development comes with massive environmental burdens and wastes. In this regard, this research also explores how these environmental and waste management standards are enforced in KSA and how proper enforcement of legislation and environment standards assists in the development of an environmentally sustainable city. KSA faces considerable challenges in the formulation and enforcement of effective waste management policies, especially on waste collection. Waste collection is a component of the solid waste management system that consists of the transfer of solid waste from the point of use to the point of treatment.¹⁹ In developing cities in Saudi Arabia, such as Jeddah, poor waste collection can lead to huge heaps along the streets or even within the residential areas. In some cases, illegal dumpsites might emerge.

Solid waste management remains one of the biggest challenges facing Jeddah. This challenge is catalyzed with the rapid pace of population growth, leading to the daily production of more than 5000 tons of solid waste.²⁰ As a result, Jeddah municipal authorities are finding it extremely difficult to cope with the problem of urban solid wastes. The management of solid waste in Jeddah faces increasing challenges from the collection of wastes from bins scattered across residential and commercial areas which are insufficient. Solid wastes are then collected

¹⁸ Surendra Kumar, *Solid Waste Management* (Northern Book Centre, 2009), 19

¹⁹ Chandrappa et al, 49

²⁰ Hakami, Bader A., and El-Sayed S. Abu Seif. "Household Solid Waste Composition and Management in Jeddah City, Saudi Arabia: A planning model." *International Research Journal of Environment Sciences* 4, no. 1 (January 2015), 3

and transported to transfer stations where they then proceed to the dumping site. Most of Jeddah's solid wastes are disposed of at a landfill facility at Buraiman.²¹ Today, it is estimated that the landfill receives more than 1.5 million tons of wastes a year. This volume of wastes significantly reduces the lifespan of the landfill. Solid wastes in Jeddah city are dominated by organics, plastics, paper and other small components. Apart from rapid population growth, one of the factors leading to poor waste management in some of these cities is the poor attitude of the people towards environmental sanitation.²² Other causes might include poor administration of waste management agencies and a lack of appropriate recycling technology for wastes.

1.2 Problem statement

KSA faces serious environmental challenges in most of its major cities due to the rapid increase in waste generation and inadequate waste collection, disposal, and treatment infrastructure. Recently, the national government launched a comprehensive environmental management strategy that targets the entire country.²³ In this strategy, the government approved a standardized system of dealing with environmental issues across the country and also proposed a waste management strategy for the main cities. According to this plan, solid waste management legislation and strategies were to be based on the universally accepted scientific approach for integrated solid waste management hierarchy. However, cities like Jeddah have a problem when it comes to enforcement of such strategies. In the last few decades, Jeddah City has experienced

²¹ Hakami, Bader A., and El-Sayed S. Abu Seif. "Household Solid Waste Composition and Management in Jeddah City, Saudi Arabia: A planning model.", 5

²² M. O. Agwu, "Issues and Challenges of Solid Waste Management Practices in Port-Harcourt City, Nigeria- a behavioral perspective," *American Journal of Social and Management Sciences* 3, no. 2 (2012):, https://www.researchgate.net/publication/283359595_Issues_and_Challenges_of_Solid_Waste_Management_Practices_in_Port-Harcourt_City_Nigeria-_a_behavioural_perspective, 94

²³ Hakami, Bader A., and El-Sayed S. Abu Seif, 6

rapid socio-economic development accompanied by rising waste generation rates and reducing waste management capacities. This has resulted in environmental pollution among other losses.

Jeddah City's current waste management systems are not able to cope with the huge volumes of wastes generated by the increasing urban population. These wastes put the city at a higher risk of environmental and health problems. Though the challenges and barriers to effective solid waste management systems are significant, there several opportunities that can be exploited to improve the environmental health of the city.²⁴ Most importantly, there is a need for the national and city authorities to formulate and enforce environmental standards targeting these solid waste problems. Currently, the priority of Jeddah city authorities is to collect and dispose of waste into the landfills with little regard to environmental protection or more sustainable solid waste management systems.²⁵ This dissertation argues that the development and enforcement of specific environmental standards on solid waste management can help to facilitate the development of modern, scientific solid waste management systems. The researcher suggests that inadequate national and municipal environment standards and enforcement strategies is a key barrier to the establishment of a sustainable modern solid waste management system in Jeddah, KSA.

1.3 Research Questions and Objectives

1.3.1 Introduction of the Proposed Solid Waste Management Laws and Regulations

²⁴ Khalid A. Alkhuzai, 49

²⁵ Hakami, Bader A., and El-Sayed S. Abu Seif, 7

The literature above that describes the background into the state of solid waste disposal calls for the improvement of the current handling of solid waste by Jeddah's authorities. For there to be sufficient reforms causing the intended positive changes on Jeddah's and Saudi Arabia's residents in general, the relevant authorities need to consider the current nature of laws and regulations guiding the process of solid waste management. A lot of steps have been taken, some achieved to the good of the residents and the environment around Jeddah since the 2001 regulations were implemented. However, the state of solid waste management keeps deteriorating, more so because of the rising population in Jeddah. The laws and regulations work, but they need to be worked on to ensure that the waste management solutions implemented are sustainable. They need to be investments by the authorities that will actually cause identifiable and measurable impact on the residents, in terms of improved overall environmental state and for the city in terms of lower costs used to handle the problem and similar problems in the future.

Conventionally, the task of storage, collection, and disposal of solid wastes falls within the jurisdiction of the local authorities and are governed by the city or municipal by-laws. The city or municipal authority determines the legal and administrative arrangements in relation to solid waste collection and disposal. In KSA, the first comprehensive Saudi Arabian national environmental legislation was enacted in September 2001 in the form of General Environmental Regulation.²⁶ This new regulation outlined a wide range of prohibitions on pollution, air, and land and water contamination. The laws focused on the activities that lead to the generation of these wastes. Presently, local authorities, such as Jeddah city management, are tasked with the day to day management of wastes and ensuring the waste management approaches are sustainable. According to Magram, there is a growing concern about the perceived failures of

²⁶Anjum, Muzammil, et al. "Solid waste management in Saudi Arabia: A review, 18

Jeddah city management to address the existing waste problem effectively.²⁷ This has even led to suggestions that the national government should take full responsibility for waste management. Therefore, this thesis intends to answer two research questions about solid waste management in KSA. The first question is related to the waste management legal framework in KSA while the second question focuses on policies to ensure the sustainability of waste management measures.

1. How does the current environmental legal framework in KSA impact the effectiveness of solid waste management strategies in Jeddah, KSA?

In asking this question, the researcher intends to critically analyze the existing environmental and waste management laws and regulations and if they impact on the effectiveness of solid waste management measures. The researcher assesses regulatory barriers to effective solid waste management and legal challenges to the implementation of various waste management initiatives. In answering this question, the researcher focuses on the entire solid waste management approach in Jeddah from the collection, awareness creation, and disposal in landfills to reuse and recycling. It will show how the law will address already existing problems that the current laws are unable or are yet to address, case in point, the growth of dumping sites like the Almusk Lake to which Jeddah's sewage wastewater has for the last decade, especially since the environmental protection laws were enforced as early as the 2000s.

2. What kinds of policies could help to achieve sustainable solid waste management practices in Jeddah, KSA?

²⁷Magram, Saleh F. "A Review on the Environmental Issues in Jeddah, Saudi Arabia with Special Focus on Water Pollution, 125

This question addresses the sustainability challenges that waste management practices in KSA cities, such as Jeddah's face. In discussing these challenges, the researcher aims to demonstrate that Jeddah's waste management practices can be improved and there are new measures that can be implemented towards a goal of sustainable solid waste management approach. The research question looks to show that the paper will look towards similar projects that have worked in other cities that are the size of Jeddah in Saudi Arabia and around the world. The intention is to establish a mix of forward-looking policies that would be best fit for the city, and that will fall under the necessary laws and regulations. Cities with tight regulations regarding industrial emissions, greater focus on health protection, those that focus on strict environmental planning whether the cities are located in arid or wet parts of the world, and the drive to establish sustainable urban spaces have been successful, and this question looks to answering how this has been possible and how it will be for Jeddah's waste management and the related waste management issues and problems.

1.4 Roadmap

To answer the research questions, it is important to understand solid waste management approaches being used in KSA and some of the factors that influence their success. The researcher also evaluates the environmental laws of KSA and various proposals to improve waste management approaches in the country and implement a more sustainable approach to waste management in the country. In part 1, the researcher provided an overview of the problem background as well as the methodology used to answer study goals. The rest of the paper is divided into seven parts.

Part 2 introduces the methodology to be applied in synthesizing the range of information available in the field of waste management and related policies. While the Part 1 above already addresses the overview, which includes the definition of the research questions, this part consists of a recap of the research questions to justify how fit the part is in answering them. In the part is also a description of how data will be gathered and analyzed, which includes how it approaches the research questions.

Part 3 discusses the origin and impact of solid wastes in KSA. This section focuses on the sources of solid wastes in KSA and their causes, such as oil extraction, urbanization, industrialization, population growth, and economic and environmental impacts of solid wastes in KSA.

Part 4 evaluates the current legal framework on solid waste management in Jeddah, KSA. In this part, the author explores both national laws and regulations and municipal laws on waste management. In addition, the researcher reviews other related environmental laws, including Standard Waste Transportation 2012. The researcher also analyses how regulations governing activities, such as oil drilling impact on the overall waste management approach in KSA.

Part 5 assesses solid waste management challenges facing Saudi Arabia. Specifically, the researcher assesses how regulatory barriers affect effective solid waste management in KSA. Apart from the regulatory barriers, this part reviews other barriers to effective waste management, such as inadequate dumping bins, irregular waste collection, and social-cultural and religious barriers, among others.

Part 6 addresses sustainable solid waste management challenges in Saudi Arabia. Particularly, the researcher examined challenges and limitations to pertinent solid waste management legislation and how sustainability needs impact on solid waste management practices. Besides, the researcher addresses concerns regarding solid waste management in urban centers and other concerns in this part.

Part 7 examines the practices of the national and municipal agencies in dealing with the challenges facing solid waste management in Jeddah, Saudi Arabia. The section also investigates the role of individuals and communities in addressing the problem of waste management and various methods used in various urban areas and communities to manage wastes.

Part 8 analyses alternative approaches to solid waste management that KSA can adopt to improve the current state of waste management. In this part, the researcher discusses options, such as the strengthening of the laws governing law enforcement, cleaning of the dumpsites, cooperation among relevant parties, and renovation of current dumpsites, among others.

Part 9 provides a summary of the study and findings. In this section, the researcher discusses the practical as well as the theoretical implications of these findings. The research also reviews the findings and determines if they are consistent with the thesis statement.

2 METHODOLOGY

This section describes how the research was conducted, i.e. the strategies and procedures adopted by the researcher in an attempt to answer the research questions. The research outlines the research approach and strategy, including information sources. Finally, the researcher provides a roadmap on the overall structure of the dissertation.

2.1 Research Approach and Strategy

This thesis relies on comparative law methodology and critical literature analysis approaches in data collection and analysis. Comparative law methodology emerged as the necessary tool for harmonization of law towards the end of the 20th century.²⁸ Though the primary goal of this methodology is to compare legal systems, it can also be applied to generate knowledge regarding the evolution of laws, the development of legal systems and harmonize local, national and international laws. Studies have shown that this methodology is also applicable when the study aims to make some sections of the domestic law more coherent.²⁹ In this research paper, comparative law is applicable because of the commonality of problems faced by mostly urban spaces in different parts of the world. There is also the sense that the comparative law methodology is applicable because Saudi Arabia, just like other nations and kingdoms around the world, is a member of the United Nations, which means that its environmental laws and regulations are bound by the United Nations Environment Programme's Division of Environmental Law and Conventions.³⁰ The sense, therefore, is in the fact that since

²⁸ Adams, Maurice, Jaakko Husa, and Marieke Oderkerk. *Comparative Law Methodology*. Gloucestershire: Edward Elgar Publishing, 2017, 19

²⁹ Monateri, P. G. *Methods of Comparative Law*. Gloucestershire: Edward Elgar Publishing, 2012, 33

³⁰ Yang and Percival, 09

regulations, laws and conventions different authorities in the various urban spaces and cities have worked to improve and almost completely overhaul the poorly functioning waste management programs and policies, they too will work in Jeddah, and that they will be within the kingdom's capabilities and in line with UNEP's environmental rule of law, whose aims are the progressive development of environmental law, the continued protection of human rights with regard to the improvement of their state of life and the conditions in which they dwell, the addressing of environmental crimes within the bounds of the kingdom's laws and regulations and jurisdictions, and the ability to generate a level of capacity building for all stakeholders relevant to the improvement of the waste management policies in the kingdom.

In this regard, the methodology is appropriate in evaluating the national and municipal environmental standards in KSA and how they influence solid waste management programmers, in comparison with the existing laws and environmental standards that are known to have been successful in establishing solid waste management programs. This approach is also justified when the goal of the study is to come up with recommendations that will improve Jeddah's own legal system while looking at it from the context that works for the city's good and for the benefit of its residents, which, in sense, will be properly suited for the authorities and the government. In this case, the importation of foreign rules and solutions may not work due to differences in context; thus, a thorough contextual approach to comparative law is applied in the study.³¹ That is, the author focuses on the legal evolution of environmental standards and how they apply to solid waste management systems in Jeddah. The comparative law methodology will look at foreign rules and solutions that are deemed successful or close to successful, then

³¹ Jonker, Jan, and Bartjan Pennink. *The Essence of Research Methodology: A Concise Guide for Master and PhD Students in Management Science*. Berlin: Springer Science & Business Media, 2010, 41

compare them with Jeddah's own, but they will not be imported to the proposed laws, regulations, rules, and solutions to waste management. They will only be considered from the comparison, with great attention being paid to just how significant they are and how they could help create and phrase laws and regulations that could solve the current problems faced by Jeddah's waste management.

In addressing the research question (i), the author seeks to understand what the law allows and how solid waste management practices can be legally implemented. To achieve this objective, the author applies a comparative law method encompassing critical reasoning, evaluation of the law, discussions of how the law operates, and analysis of the loopholes that exist in the design and implementation of KSA environmental laws. Generally, comparative law methodology focuses on various aspects of legal doctrine.³² This approach is selected for this question as it allows for an engaging and critical discussion of the existing laws compared to those in other sectors or countries. Given that environmental problems are universal and contextual, there is a lot that can be learnt from past studies and the current context. By using this approach, the researcher can also question the design of environmental legal doctrines in the Kingdom and demarcate responsibilities of various actors, i.e., local and national actors in relation to solid waste management. In the final part of answering this question, the author evaluates the desirability and possibility of developing a new legal framework to address the raging problem of solid waste management in Jeddah.

³²Paris, Marie-Luce, *The Comparative Method in Legal Research: The Art of Justifying Choices* (June 21, 2016). To be published in Laura Cahillane and Jennifer Schweppe (eds), *Legal Research Methods: Principles and Practicalities* (Clarus Press 2016); UCD Working Papers in Law, Criminology & Socio-Legal Studies Research Paper No. 09/16, 32

The data used in answering this question was gathered from legal documents and policies on waste management by Jeddah city's management authority. The researcher also gathered data on environmental laws and policies from the national government. Consequently, the author compared the role of city authorities and the national and international environmental laws to identify legal and regulatory obstacles to effective design and implementation of solid waste management policies. The researcher also relies on past studies to evaluate the role of legislation and regulations in waste management and how new regulations could help to improve waste management in KSA. In addition, the researcher compares the solid waste management legal framework in KSA with best practices around the world, hence the comparative law methodology's application. The goal of this comparison is to determine the weaknesses of KSA's regime and use the established solid waste management best practices as a guide to recommend appropriate measures to improve KSA's legal regime.

To answer the question (ii), the researcher critically analyses the existing literature. In this method, the researcher reviewed scholarly articles and other secondary sources, such as books and technical reports on waste management. Usually, a critical literature review encompasses describing, summarizing, and critically evaluating various sources in relation to the research problem which is under investigation.³³ This approach was selected as it helps to identify the gaps that exist in the current measures to deal with solid waste management. In reviewing technical reports, the researcher gets to understand why the current systems of waste management in KSA are failing from an expert point of view. This approach also helps the researcher to understand contrasting perspectives into the solid waste management issue in

³³ Monateri, 41

KSA.³⁴ That is a critical evaluation of sources that provides an objective view of various challenges facing waste management in KSA and the impact of waste management problems, especially in cities.

Based on the methodology outlined above, this project specifically addresses the following issues in order to answer the project questions stated above:

- Discusses the origins and impact of solid wastes in Saudi Arabia
- Evaluates the current legal framework in dealing with solid waste management in Jeddah, Saudi Arabia
- Examines the solid waste management challenges facing Saudi Arabia cities
- Explore the challenges to the sustainability of solid waste management systems in Saudi Arabia
- Illustrates how national and municipal agencies are overcoming solid waste problems in Jeddah, KSA
- Recommend how the current solid waste management practices in Jeddah can be improved considering the municipal, national, and international contexts of environmental laws and regulations, rules, policies, and solutions

³⁴Baig, Mirza B., et al. "Understanding and addressing waste of food in the Kingdom of Saudi Arabia."6

3 ORIGIN AND IMPACTS OF SOLID WASTES IN THE KINGDOM OF SAUDI ARABIA

3.1 Introduction

This section evaluates the origin and sources of solid wastes in the Kingdom of Saudi Arabia. The researcher understands that Saudi Arabia has experienced massive population growth, urbanization, and industrialization, especially in its large cities. These trends are expected to have a significant impact on the existing solid waste management infrastructure. In addition, oil extraction has remained the economic activity in the country for decades and the main driver of urbanization and industrialization. The researcher, therefore, evaluates various forms of solid wastes associated with these economic activities.

3.2 History and Origins of the Solid Waste in Saudi Arabia

Throughout history, humans have generated massive amounts of wastes. In areas of low population density, such as rural arid areas, waste generation has always been negligible. In high population areas, such as cities, waste generation has become a mega and complex problem to address.³⁵ Though people can easily deal with biodegradable wastes, significant amounts of wastes are not of this kind. Global data on the composition of municipal wastes indicated that there was a direct correlation between the amount of biodegradable wastes (food residues) and other types of wastes, such as metals, glass, and plastics.³⁶ In regions, the researchers found that

³⁵ H. Alter, "The origins of municipal solid waste: The relations between residues from packaging materials and food," *Waste Management & Research* 7, no. 2 (1989): 108

³⁶ Garrick Louis, "A Historical Context of Municipal Solid Waste Management in the United States," *Waste Management and Research* 22, no. 4 (2004): 311, https://www.researchgate.net/publication/8253891_A_Historical_Context_of_Municipal_Solid_Waste_Management_in_the_United_States

there was a significantly low fraction of food wastes compared to plastics and metals. This implies that these non-biodegradable wastes were causing the main waste management challenge in urban areas.³⁷ This can be attributed to high population growth and industrialization. In the last two decades or so, KSA has been experiencing rapid industrialization, high population growth rate and fast urbanization. This has resulted in a massive increase in the levels of pollution and waste. Nevertheless, oil and gas industries still represent the biggest source of waste and revenues for KSA.

3.2.1 Oil Extraction Activities

The oil sector is the backbone of the economy of Saudi Arabia, as the economy heavily depends on the sector. Oil revenues impact on economic activities and employment opportunities in Saudi Arabia at a larger scale. For instance, oil extraction and related activities contribute more than 90 percent of KSA revenues. It is estimated that KSA possesses around 18 percent of the global petroleum reserves and ranks as the largest exporter of petroleum.³⁸ As such, oil and gas resources contribute up to 50 percent of the kingdom's GDP and about 70 percent of export earnings.³⁹ According to a study conducted to evaluate the importance of oil in Saudi Arabia's economy between 1991 and 2016, it was found that between 1991 and 1999, the share of oil revenues in government revenues dropped from 77.8 percent to 70.8 percent as global oil prices fell.⁴⁰ However, as a result of the rise in the price of oil from 2000, the share of oil revenues to

³⁷ Garrick Louis, "A Historical Context of Municipal Solid Waste Management in the United States, 314

³⁸ Taher, Nahed, and Bandar Hajjar. *Energy and Environment in Saudi Arabia: Concerns & Opportunities*. Berlin: Springer Science & Business Media, 2013.

³⁹ Joebenson, Francis L., et al. "A Review in Oil Exploration and Production Waste Discharges According to Legislative and Waste Management Practices Perspective in Malaysia." *International Journal of Waste Resources*, 7, no. 1, (2016), 5

⁴⁰ Khalid A. Alkhatlan, "Contribution of Oil in Economic Growth of Saudi Arabia," *Applied Economics Letters* 20, no. 4 (March 2013): 345, doi:10.1080/13504851.2012.703310.

national revenues rose from 78.8 percent in 2003 to 92 percent in 2012.⁴¹ Though the recent dip in global prices has seen the shares dip to below 70 percent as other economic sectors expand, oil still contributes a high proportion of revenues and the country is still hugely dependent on this single source.

The increasing demand for energy globally has led to an increase in the exploration and extraction of natural gases as well as mining of oils from unconventional organic-rich shale sources.⁴² However, little is known about the quantity, transport, and disposal of wastes from major extractors, such as Saudi Arabia. As a major global producer of oil, KSA also produces most of its wastes from oil extraction activities. Most of these drilling wastes are discharged offshore and onshore. Offshore drilling wastes include drilling fluids and drill solid cuttings as well as remnants of drill mud. Drilling fluids in the oil and gas drilling process include fluids used in removing and carrying drill cuttings to the surface, controlling subsurface pressures, lubrication and cooling the drill bit and providing borehole stability.⁴³ These liquids produced a type of wastes commonly referred to as ‘drilling mud.’ The process also produces wastewater that is difficult to treat due to the issue of polymer flooding and water flooding. Water flooding is produced from alkaline-surfactant-flooding (ASP), which contains various complex chemical and stable emulsion components. Apart from additives composition, water flooding also comprise of green starch, low viscosity polyanionic cellulose (PAC-LV), xanthan gum (XC-Polymer), partially hydrolyzed polyacrylamide (PHPA), potassium chloride (Merck, 99.5%),

⁴¹ Khalid A. Alkathlan, "Contribution of Oil in Economic Growth of Saudi Arabia," 345

⁴² Francis Lodungi et al., "A Review in Oil Exploration and Production Waste Discharges According to Legislative and Waste Management Practices Perspective in Malaysia," *International Journal of Waste Resources*, 2012, 20, <https://www.longdom.org/open-access/a-review-in-oil-exploration-and-production-waste-discharges-according-to-legislative-and-waste-management-practices-perspective-in-2252-5211-1000260.pdf>.

⁴³ Francis Lodungi et al., "A Review in Oil Exploration and Production Waste Discharges According to Legislative and Waste Management Practices Perspective in Malaysia," 22

sodium chloride (Merck, 99.5%), barite, caustic soda, and clouding glycol.⁴⁴ The wastewater is expected to increase with the increase of oil extraction activities within the country which are influenced by the high demands.

Drilling solids largely comprises of solids, such as barites and active solids, including bentonite, attapulgite, and carbonates. Studies indicate that barite is one of the most important additives to the drilling fluids. Barite occurs naturally in barium sulphate ore.⁴⁵ It is a high-density material that is effective in controlling down-hole pressure during the exploration and development phases of the offshore well drilling. Thinner, such as lignosulfonates, lignite, and tannins, as well as surfactants used, such as emulsifiers and viscosities, also make up solid wastes. Apart from those used in drilling, solid wastes in the extraction of oil can also include clays, shales, anhydrides, empty bags, pallets, and other miscellaneous disposable materials.⁴⁶ Drilling cutting materials encompass crushed rock cuttings from boreholes, which have returned to the surface with the drilling fluid.

Drilling mud contains wastes, such as base fluid and solid and liquid additives, that allow for a good drilling performance. These wastes are in the form of water, oil, and other organic fluids. These waste materials also contain weighting material, such as bentonite and barite.⁴⁷ Additives are also used to enhance the technical performance of the mud. These additives include viscosities, such as polyacrylates, and other organic polymers, emulsifiers, such

⁴⁴ Francis Lodungi et al., 28

⁴⁵ Alter, H. "The origins of municipal solid waste: The relations between residues from packaging materials and food." *Waste Management & Research* 7, no. 2 (1989), 107

⁴⁶ Maloney, Kelly O., and David A. Yoxtheimer. "Production and disposal of waste materials from gas and oil extraction from the Marcellus Shale Play in Pennsylvania Environmental Practice." *Environmental Practice* 14, no. 4 (2012), 281, doi:10.1017/S146604661200035X.

⁴⁷ OPEC. "Saudi Arabia facts and figures." *Organization of Petroleum Exporting Countries*, (2012), 1

as alkyl acrylate sulphonate and polyethylene oxide as well as pH and shale control agents.⁴⁸ Most of these additives can introduce potentially introduce toxic compounds into the fluids.

The process of oil production and refining produces a type of waste called petroleum sludge. Petroleum sludge refers to a complex mix of varying quantities of waste oil, wastewater, sand, and mineral matter. Petroleum industries in Saudi Arabia are responsible for the generation of large quantities of sludge, which is one of the main sources of environmental pollution in KSA. These industries are also responsible for oily sludges, which are hazardous.⁴⁹ Unlike other wastes, sludges cannot be disposed of as landfill even if they are de-oiled. Most sludges from the petroleum industry result from accumulation in crude oil tanks, refinery products tanks, and desalters. Sludges comprise about 40 percent oil.⁵⁰ Oily sludge is not only produced during the production of oil products but can also occur during storage in tanks. These sludges must be treated and made harmless before they can be disposed of. After treatment, land-farming is the most preferred method of disposing of these wastes. Land-farming encompasses the use of natural biological, chemical, and physical processes in the petroleum-contaminated soil to transform organic contaminants.⁵¹

⁴⁸Maloney, Kelly O., and David A. Yoxtheimer. "Production and Disposal of Waste Materials from Gas and Oil Extraction from the Marcellus Shale Play in Pennsylvania." *Environmental Practice*, 14, (2012), 281

⁴⁹OPEC. "Saudi Arabia facts and figures, 1

⁵⁰Maloney, Kelly O., and David A. Yoxtheimer. "Production and Disposal of Waste Materials from Gas and Oil Extraction from the Marcellus Shale Play in Pennsylvania, 282

⁵¹Baig, Mirza B., et al, 9

3.2.2 Urbanization and Industrialization

Urbanization is the transfer of population from rural areas to urban areas leading to a gradual increase in the proportion of people living in urban areas.⁵² Specifically, urbanization is the process through which cities and towns are formed and become larger as people prefer to live in central areas.⁵³ People prefer to live in cities or urban areas due to various economic and cultural benefits, such as greater opportunities to access the labor market, better education, and housing are reduced time spent in transportation. According to the United Nations, more than 65 percent of the population in developing countries and 75 percent in developed countries will be living in urban areas by 2050.⁵⁴ This projection indicates that there will be approximately 3 billion Africans and Asians moving to the urban areas. The United Nations also noted that almost all the global population growth between 2017 and 2030 will take place in cities with around 1.1 billion new urbanites in the next 13 years. This rapid urbanization will be facilitated by conditions, such as density, proximity, diversity, marketplace access, and competition, which are necessary for a positive urban environment.⁵⁵

Saudi Arabia is one of the developing countries that have experienced rapid urbanization in the last three decades or so. Saudi Arabia has been experiencing large numbers of people from rural and nomadic habitats and foreign immigrants moving to the country's urban areas.⁵⁶ The rapid growth in urban population and land use has had a significant impact on the nation's

⁵² T. Gries and R. Grundmann, "Fertility and modernization: the role of urbanization in developing countries," *Journal of International Development* 30, no. 3 (2018): 495

⁵³ S. Eckert and S. Kohler, "Urbanization and health in developing countries: a systematic review," *World Health & Population* 15, no. 1 (2014): 10, doi:10.12927/whp.2014.23722.

⁵⁴ S. Eckert and S. Kohler, "Urbanization and health in developing countries: a systematic review, 11

⁵⁵ T. Gries and R. Grundmann, "Fertility and modernization: the role of urbanization in developing countries," *Journal of International Development* 30, no. 3 (2018): 499

⁵⁶ Ahmed M. Al Bassam, "Urbanisation and Migration in Saudi Arabia: The Case of Buraydah City," (PhD diss., University of Leicester, 2011), <https://lra.le.ac.uk/bitstream/2381/10152/1/2012ALbassamAMApd.pdf>, 33

capacity to plan and systematically absorb populations. Between 1950 and 2000, KSA's urban population jumped from 20 percent to around 80 percent. It is estimated that more than 90 percent of KSA's population will be living in urban areas by 2050.⁵⁷ In actual numbers, the urban population of KSA has increased from just over 650000 in 1950 to more than 24 million in 2015. This implies that the urban population has multiplied 65 times in the last 65 years. By 2050, it is estimated that 35.8 million Saudis will be living in urban areas.⁵⁸

Industrialization and urbanization are some of the main generators of wastes.

Urbanization is mostly associated with various types of wastes, especially food wastes. Studies show that the rapid growth of communities in a single area creates the challenge of dealing with increased food waste or urban food waste.⁵⁹ Food wastes refer to food products that can no longer be used due to unused products, expiration, or spoilage. The increase of food waste leads to environmental problems, such as an increase in the production of methane gas and the attraction of disease vectors. Currently, landfills in urban areas are the leading cause of methane resulting in adverse effects on the ozone and health of individuals. Furthermore, accumulation of food waste increases fermentation thus enhancing the risk of rodent and bug migration.⁶⁰ These migrations also imply migration of disease vectors thus increasing the potential of diseases spreading humans.

⁵⁷ Antar A. Abou-Korin and Faez S. Al-Shihri, "Rapid Urbanization and Sustainability in Saudi Arabia: The Case of Dammam Metropolitan Area," *Journal of Sustainable Development* 8, no. 9 (2015): 2, <https://pdfs.semanticscholar.org>

⁵⁸ Antar A. Abou-Korin and Faez S. Al-Shihri, "Rapid Urbanization and Sustainability in Saudi Arabia: The Case of Dammam Metropolitan Area," 4

⁵⁹ Cecilia Tacoli, Gordon McGranahan, and David Satterthwaite, *Urbanization, rural-urban migration and urban poverty* (London: International Institute for Environment and Development, 2015), 129

⁶⁰ T. Gries and R. Grundmann, 502

On the other hand, industrialization refers to a period where a country transforms from an agrarian society to an industrial society. The transition encompasses extensive re-organization of the economy and greater emphasis on manufacturing.⁶¹The oil industry is the largest in Saudi Arabia. Most of the important industries in the cities are in the petrochemical sector. These industries release a lot of wastes into the environment. It must be noted that despite the best efforts by the government, rapid industrialization has implied that damage from waste is increasing at a high rate.⁶²During this period, the country produces a massive amount of complex wastes than in the past. Industrial wastes refer to wastes, which result from industrial activity and they include any material that has been rendered useless in the process of production.⁶³These wastes include dirt and gravel, scrap metals, chemicals, and food wastes from restaurants, scrap lumber, and so on. Industrial wastes include solid, liquid and gaseous wastes. Some of these wastes can also be hazardous by being combustible, toxic, reactive or radioactive. Industrialization leads to urbanization that can easily augment the problem of waste management. For instance, the rapid growth of urban areas as a result of industrialization creates new challenges to waste management, such as inadequate infrastructure, poor environmental planning, budgetary constraints, and overpopulation.⁶⁴As a result, industrial wastes are mixed with other municipal or urban wastes thus making it hard to assess each category of wastes accurately. It is estimated that KSA produces more than 100 million tons of industrial wastes annually.⁶⁵

⁶¹ Cecilia Tacoli, Gordon McGranahan, and David Satterthwaite, *Urbanization, rural-urban migration and urban poverty*, 59

⁶²Taher, Nahed, and Bandar Hajjar, 27

⁶³ Heister and Harrison, 49

⁶⁴ Martin F. Lemann, *Waste Management* (Bern: Peter Lang, 2008), 39

⁶⁵Joebenson, Francis L., et al. "A Review in Oil Exploration and Production Waste Discharges According to Legislative and Waste Management Practices Perspective in Malaysia, 6

Joebenson et al. indicated that most of the wastes generated from industries and cities are municipal wastes. This implies that industrialization comes with a significant environmental burden.⁶⁶ In the context of urbanization, studies have indicated that most of the developing countries are unable to deal with the problem of the rapid rise in amounts of wastes generated. According to recent studies, KSA's three main cities of Riyadh, Jeddah and Dammam account for more than 6 million tons per annum of wastes. According to Maloney and Yoxtheimer, municipal solid wastes, especially household waste, were found to be the second-largest category of wastes by a source in KSA.⁶⁷ These wastes were mostly organic materials that consisted of recyclables, such as glass, paper, metals, and plastics. This amount highlights the significance of the waste problem faced with these local authorities. Apart from the oil and gas industry, Saudi Arabia also has the largest tourism industry in the Middle East. The growth of the tourism industry in Saudi Arabia has been linked to the presence of two holiest destinations for Muslims, i.e., Masjid-ul-Haram in Makkah and Masjid-e-Nabwi in Medina.⁶⁸ Millions of Muslims from around the globe travel to these destinations to participate in Pilgrimage. With the pilgrim numbers increasing annually, services and facilities, such as transportation, food supply, accommodation, and security, have been adversely affected. Furthermore, cities, such as Makkah, are experiencing a significant increase in the amount of solid wastes being generated. According to a recent study, the amount of solid waste generated in Makkah city alone was estimated to be more than 1 million ton a year.⁶⁹ During normal months, Makkah generated 2600

⁶⁶Joebenson, Francis L., et al, 8

⁶⁷Maloney, Kelly O., and David A. Yoxtheimer, 285

⁶⁸Zafar, Salman, 1

⁶⁹Magram, Saleh F, 129

tons and 4600 tons during the months of Ramadan daily. In 2014, a study found that more than 100000 tons of wastes generated in Makkah were from foreign tourists.⁷⁰

Saudi Arabia and the rest of the Arab countries are currently facing problems of increasing urbanization, high food demand, and the need for housing that can sustain standard life patterns. Currently, the agency in charge of waste management in Saudi Arabia only focuses on waste disposal and not the energy recovery from it.⁷¹ Moreover, the government acknowledges the increasing demand for waste management solutions and the need to invest heavily in solving this problem by adopting more effective waste management approaches, such as waste-to-energy technologies. Noteworthy, governments and government agencies in developing countries normally struggle with the problem of collecting, treating and disposing of wastes; thus, these wastes lead to massive impacts on human and environmental health.⁷² Industrialization and urbanization also lower access to compostable wastes as a percentage of non-compostable matter continue to increase due to greater utilization of plastics by urban households and chemical pollutants. In most urban areas, household solid wastes include plastics, paper, glass, metals and organics and others. If these wastes are disposed of correctly, they can help in sustaining environmental quality and proper human health while also preserving natural resources.⁷³ One must acknowledge that household solid wastes have several direct and indirect impacts on the environmental and human welfare, including damage on materials, loss of aesthetic value, adverse changes on ecosystem structure, and climate change.

⁷⁰Islam, Badrul. "Petroleum sludge, its treatment and disposal: A review." *Int. J. Chem. Sci.* 13, no. 4, (2015), 1588

⁷¹Shahzad, K., et al, 3

⁷²Khalil, M. A, 348

⁷³Maloney, Kelly O., and David A. Yoxtheimer, 289

Furthermore, major Saudi Arabia cities are faced with the problem of the rapid rise of the population, especially expatriates working in the new industries. This has led to rapid urbanization without proper waste management strategy. As a result, waste disposal tools, such as dumping bins and transportation vehicles, are incredibly insufficient.⁷⁴ Due to this, a significant amount of wastes ends up not being collected. Another problem facing waste collection in Saudi Arabia is the issues of irregular waste collection. Due to the lack of sufficient policies and regulations dealing with waste management, most cities lack the technical, organizational and financial capability to deal with the high rate of waste generation.⁷⁵ These results in a huge volume of wastes being left to lie around as collection becomes more irregular. Urbanization has been identified as one of the major causes of ground, water and air pollution in Saudi Arabia. Urbanization in Saudi Arabia is also threatening marine life and ocean ecosystems. For example, the country is experiencing massive coastline constructions from residential to tourism products.⁷⁶ As a result, there have been significant increases in the amount of untreated sewage that ends up in the ocean and as excess trash in cities. Construction and human activities have also led to damages to the coastal reef damage and an increase in ocean acidity. The city of Jeddah and other urban areas are facing considerable problems of heavy traffic leading to roadside contamination and high carbon emissions. Besides, car usage and city life contribute significant amounts of heavy metals being released in urban soils.⁷⁷ These metals are harmful to plants, animals and humans and can be poisonous when ingested.

⁷⁴Oyedele, Olufemi. "Challenges of urban solid waste management in developing countries." *The 31st International Conference on Solid Waste Technology and Management Philadelphia, PA USA April 3-6, 2016* (n.d.), 5

⁷⁵Oyedele, Olufemi. "Challenges of urban solid waste management in developing countries" 9

⁷⁶Faisal K. Alturki, 55

⁷⁷Taher, Nahed, and Bandar Hajjar. *Energy and Environment in Saudi Arabia: Concerns & Opportunities*. Berlin: Springer Science & Business Media, 2013, 19

Nevertheless, major oil companies, such as Aramco, have tried to join municipal and national government efforts to deal with the problem of wastes efficiently. These corporations and municipal councils have, therefore, increased funding to counter the effects of improper waste management. Furthermore, there have been new policies for the elimination of contentious waste management approaches, such as the burning of disposed waste and plastic materials.⁷⁸ In this regard, the industrial sector is putting more emphasis on common methods of waste management, such as landfills, incineration, recycling, and energy conservation.⁷⁹

3.2.3 Population Growth

Population growth refers to an increase in the number of people with a region. Since the 1990s, most of the world economies, especially in Sub-Saharan Africa, the Middle East, South Asia, and South-East Asia, have witnessed a rapid rise in population. According to the United Nations' global human population estimates, the world population grows at a rate of 83 million people annually.⁸⁰ It is expected that the world will continue growing at this rate with the total population reaching 8.6 billion by mid-2030, 9.8 billion by mid-2050 and 11.2 billion by 2100.⁸¹ Rapid population growth is another major challenge to waste management. As the population continues to grow, the rate of growth of wastes has been estimated to be even faster. The rapid increase of population is the main contributor of the increase in municipal solid waste making it hard for its management.⁸² It is because of hygiene problems and inadequate expensive

⁷⁸Demirbas, Ayhan, 11

⁷⁹Agwu, M. O, 88

⁸⁰ Sheldon Anderson, Mark A. Peterson, and Stanley W. Toops, "Global Population Projections," *International Studies*, 2018, 420, doi:10.4324/9780429495151-18.

⁸¹ Hazel Barrett and Angela Browne, "Global Crises? Issues in Population and the Environment," *Contested Worlds*, 2017, 134, doi:10.4324/9781315259406-4.

⁸²Abd Manaf, Latifah, Mohd Armi Abu Samah, and Nur Ilyana Mohd Zukki. "Municipal solid waste management in Malaysia: Practices and challenges." *Waste management* 29, no. 11 (2009): 2902-2906.

land that can be used for disposal of the waste; thus, exerting a lot of pressure on waste management.⁸³ In the last ten years, studies indicate that the amount of wastes generated per person per day has increased from 0.64 kg in 2005 to 1.2 kg in 2015.⁸⁴ An increase in population has also resulted in changes in consumption patterns, economic development, household incomes and rate of urbanization.

In world cities, a total of 2.01 billion tons of solid waste are generated per day, amounting to a footprint of 0.74 kilograms per person per day.⁸⁵ Due to the current rate of world population growth and urbanization, annual waste generation is expected to increase by more than 70 percent from 2016 levels to 3.40 billion tones in 2050. Residents in developing countries, such as Saudi Arabia, particularly the urban poor, shall bear the brunt of unsustainably managed waste. In these countries, up to 90 percent of waste is often disposed of in unregulated dumps or are openly burned.⁸⁶ As a result, the waste problem in developing cities has been identified as serious health, safety and environmental risks. Population pressure also leads to wastes being heaped in residential areas thus serving as a breeding ground for disease vectors.

In KSA, population growth has been a precursor to several environmental and health challenges include clogged drainage systems in cities, respiratory diseases, and others. Currently, Saudi Arabia has a population of more than 29 million people and generates more than 15 million tons of solid wastes annually. More than 75 percent of this population lives in cities and urban areas. Studies also indicate that the per capita waste generated per person is between 1.5 to

⁸³ Matsunaga, K. O., and Nickolas J. Themelis. "Effects of affluence and population density on waste generation and disposal of municipal solid wastes." *Earth Engineering Center Report* (2002): 1-28.

⁸⁴Islam, Badrul. "Petroleum sludge, its treatment and disposal: A review, 1589

⁸⁵ Sheldon Anderson, Mark A. Peterson, and Stanley W. Toops, "Global Population Projections," 422

⁸⁶ Hazel Barrett and Angela Browne, "Global Crises? Issues in Population and the Environment, 139

1.8 kg per person per day.⁸⁷ Assuming that the current rate of population growth of 3.4 percent, urbanization of 1.5 percent and economic development of 3.5 percent continues, the waste generation will double to 30 million per year by 2033.⁸⁸ Saudi Arabia's major urban areas are densely populated with an average population growth rate of more than 5 percent annually.⁸⁹ Due to this rapid population growth rate, most of these urban areas are unable to handle the problem of wastes. Furthermore, urban areas, such as Jeddah, are witnessing a manufacturing boom, which translates to an increase in the amount of wastes generated. As a result, the existing waste management systems in these cities have been dwarfed by population pressure and rapid industrialization.

Besides, rapid urbanization and unprecedented population growth in cities and urban areas have led to acute management problems of solid wastes in the country. Though solid waste management is a vital service that relates to public health and the environment, it is still down on the priority list of urban planning and design practices.⁹⁰ Some studies have noted that the lack of prioritization of solid waste management comes from the public apathy from city residents and service providers.⁹¹ For effective urban planning, there is a need for proper strategies on waste reduction, separation, processing, management, recycling and reuse. There is also a need to invest in low-cost alternatives to open incineration of solid waste. In cases where incineration is unavoidable, combustion technologies with strict emissions controls are essential. Besides, best planned urban areas and cities have improved the collection, management, and disposal of urban

⁸⁷Ouda, Omar K., and Huseyin M. Cekirge, 270

⁸⁸Shahzad, K., et al, 5

⁸⁹Joebenson, Francis L., et al, 33

⁹⁰ Nizami, Abdul-Sattar. "Recycling and Waste-to-Energy Prospects in Saudi Arabia

⁹¹IBP, 67

waste as a measure to improve both the climate and health.⁹² Cities can use anaerobic digestion systems to capture methane gas from sewage, livestock manure and landfill solid waste and use them to produce cooking and heating fuel.

As a result of high population growth in urban areas, studies show that solid wastes have become the main component of wastes generated in Saudi Arabia.⁹³ Solid wastes include plastics, wood materials, food wastes, glasses, and scrap metals, among others. With a lack of national policy towards solid waste management, municipalities, and urban areas are left with the sole responsibility of addressing the waste problems. These municipal and urban authorities, in most cases, lack the technologies to address the problem. As a result, wastes are not properly sorted while others end up being litter on the environment.⁹⁴ Furthermore, municipal and urban authorities lack sufficient staff to help in addressing the problem of wastes thus leading to improper waste management, especially in major cities, such as Jeddah. Pollution in Saudi Arabia also rises seasonally due to religious reasons. For instance, studies have established that KSA's main cities tend to attract millions of Muslims from around the world during the month of Ramadan. Saudi Arabia is a major pilgrimage destination for Muslims around the world. These pilgrimages see more than 10 million Muslims visit the country every year almost at the same time. This number of people put a huge strain on the country's waste management capacity. During these months, waste disposals increase by more than 1 million tones.⁹⁵

⁹² Anjum, Muzammil, et al, 19

⁹³ Al Humid, Hatem A., Husnain Haider, Saleem S. Al Saleem, Majed Alinizzi, Md Shafiquzaman, and Rehan Sadiq. "Performance Assessment Model for Municipal Solid Waste Management Systems: Development and Implementation." 7

⁹⁴ Mirza B. Baig, Mirza B., Khodran H. Al-Zahrani, Felicitas Schneider, Gary S. Straquadine, and Marie Mourad. "Food waste posing a serious threat to sustainability in the Kingdom of Saudi Arabia – A systematic review." 12

⁹⁵ Oyedele, Olufemi, 13

Finally, improper dumping of solid wastes is also a major impediment to waste management in KSA. Currently, Saudi Arabia lacks a standardized and developed strategy for waste management. The country is also yet to adopt the latest scientific approaches to waste management. As a result, the problem of illegal waste disposal is still prevalent in the country. Furthermore, the expansion of cities like Jeddah has also changed the dynamics of city settlements.⁹⁶ For instance, informal settlements have emerged at a rapid rate this straining the existing waste management system leading to illegal waste disposal. On solid waste management, studies showed that effective enforcement of environmental standards benefits the society in several ways. Effective solid waste management legislations help in reducing environmental pollutions and exposure to diseases by humans and animals among other benefits.⁹⁷

3.3 Stages of Solid Waste Management in Jeddah, Saudi Arabia

Solid waste management practices are different across countries, regions, residential, and industrial sectors. For instance, developed and developing countries have contrasting approaches to waste management.⁹⁸ The contributing factors to this include the number of resources dedicated to waste management, technical expertise and technology among other factors. In most cases, waste management practices are aimed at dealing with municipal solid waste, which forms the largest proportion of wastes created from household, industrial and commercial activity. In

⁹⁶*Energy and Environment in Saudi Arabia: Concerns & Opportunities*. Berlin: Springer Science & Business Media, 2013, 55

⁹⁷ Hosetti, B. B. *Prospects and Perspective of Solid Waste Management*. New Delhi: New Age International, 2006, 47

⁹⁸Editorial Board/Aims & Scope". *Waste Management*. 34 (3): IFC, 14 doi:10.1016/S0956-053X(14)00026-9.

general, waste management strategies in most countries are designed based on four principles of the waste hierarchy, lifecycle of a product, resource efficiency and polluter-pays principle.⁹⁹

Waste hierarchy can be described as the 3Rs of waste management, i.e., reduce, reuse, and recycle. The waste hierarchy is the main pillar of most waste management strategies.¹⁰⁰ The primary goal of the waste hierarchy is to maximize the benefits an individual or organization gets from products while minimizing the amount of end waste. The waste hierarchy is understood as a pyramid as policies are developing to effect waste problems at different stages of the pyramid. At the base of the pyramid, the waste minimization strategy should aim at preventing the generation of waste.¹⁰¹ At the next step, the strategy should seek alternative uses of wastes while at the top of the pyramid; the strategy should either recycle or attempt to recover some materials.¹⁰² The final action of any conventional waste management strategy is to dispose of the waste into landfills or incineration.

Another important principle to consider in solid waste management strategy is the life cycle of a product. The life cycle of a product encompasses design, manufacturing, distribution, and primary use. Every stage in the product life cycle creates new opportunities for policy intervention on ways to minimize the product waste potential and extend its use.¹⁰³ The goal of the product life-cycle analysis is, therefore, to ensure optimization of the use of the world's

⁹⁹Chen, Dezhen; Yin, Lijie; Wang, Huan; He, Pinjing (December 2014). "Pyrolysis technologies for municipal solid waste: A review". *Waste Management*. **34** (12): 2470, doi:10.1016/j.wasman.2014.08.004

¹⁰⁰"Glossary of environmental and waste management terms". *Handbook of Solid Waste Management and Waste Minimization Technologies*. Butterworth-Heinemann. 2003. 390. doi:10.1016/B978-075067507-9/50010-3

¹⁰¹Syed Shatir, A. Syed-Hassan; Wang, Yi; Hu, Song; Su, Sheng; Xiang, Jun (December 2017). "Thermochemical processing of sewage sludge to energy and fuel: Fundamentals, challenges and considerations". *Renewable and Sustainable Energy Reviews*. **80**: 898. doi:10.1016/j.rser.2017.05.262

¹⁰²Chen, Dezhen; Yin, Lijie; Wang, Huan; He, Pinjing (December 2014), 2471

¹⁰³Syed Shatir, A. Syed-Hassan; Wang, Yi; Hu, Song; Su, Sheng; Xiang, Jun (December 2017). "Thermochemical processing of sewage sludge to energy and fuel: Fundamentals, challenges and considerations". 902

limited resources through avoidance of unnecessary waste generation. Additionally, resource efficiency is an important component of the waste management process. The principle of resource efficiency encompasses understanding that economic growth and development cannot be sustained at the current production and consumption patterns.¹⁰⁴ Overall, humanity extracts more resources from the earth to produce goods at a rate that the world cannot replenish.¹⁰⁵ Therefore, resource efficiency implies a reduction of the environmental impact of the production and consumption of these goods. The final principle is the polluter-pays principle, which ensures that the polluting party pays for the adverse impact on the environment. In relation to waste management, this principle ensures that the waste generator pays appropriately for the disposal of the unrecoverable material.¹⁰⁶

Solid waste management encompasses activities and actions, which are necessary for managing wastes from the inception to the final disposal. These activities include collecting, transporting, treating, and disposing of wastes. Waste management processes also include monitoring and regulations.¹⁰⁷ Countries around the world have varying approaches to waste management. In Jeddah, Saudi Arabia, stages of waste management can be ranked depending on the sustainability and relative environmental benefits of every stage. Basically, Saudi Arabia adopts a conventional waste management strategy that encompasses recycling, reusing, energy recovery and reducing. With final waste disposal inevitable, the landfill is the biggest component within the waste management pyramid.¹⁰⁸ Saudi Arabia largely uses landfill as it is a simple and low-cost technology compared to other methods of waste management. Despite using this

¹⁰⁴Anjum, Muzammil, et al, 23

¹⁰⁵"Glossary of environmental and waste management terms", 402

¹⁰⁶Editorial Board/Aims & Scope, 19

¹⁰⁷Salman, Zafar. "Solid Waste Management in Saudi Arabia, 1

¹⁰⁸Khalil, M. A, 348

traditional approach to waste management, the focus remains minimization and reduction of landfill waste quantities. Studies simplify waste management options into reuse, recycling, reduce and disposal.¹⁰⁹

i. Waste Reduce

Solid waste reduction measures are intended to reduce the overall amount of wastes generated from various activities within the country. The goal of waste reduction policies is to minimize the adverse environmental impacts on people's lifestyles.¹¹⁰ In KSA, waste reduction measures largely comprise of awareness creation and consumer sensitization on impacts of wastes. Under this stage of waste management, consumers are challenged to reduce consumption and reevaluate their consumption patterns to adopt patterns, which are in the best interest of the society, personal health, and the natural environment.¹¹¹ Consumers are also informed about the sustainability of the products they policies. With the population and economic growth, effective waste reduction policies are some of the most important steps in controlling the amount of wastes generated within the country.¹¹²

ii. Waste Reuse

Waste reuse is another important component of the waste management hierarchy in KSA. In this policy initiative, material resources are considered to be at the heart of KSA's economy and must be consumed responsibly. These material resources allow the citizens to meet their

¹⁰⁹Anjum, Muzammil, et al, 25

¹¹⁰ Martin F. Lemann, *Waste Management*, 48

¹¹¹ Abdou, M. H. "Health impacts on workers in landfill in Jeddah City, Saudi Arabia." *J Egypt Public Health Assoc*, 82, no. 3, (2007), 320

¹¹² Chakibi, Sanaa. "Saudi Arabia Releases 9 New Environmental Laws." *EHS Journal*, January 2013, 11

basic human needs, generate economic growth, and create social value.¹¹³ However, the current use of resources in KSA is considered unsustainable as a lot of materials are discarded as wastes. The country's waste management strategy must, therefore, preserve the stock of material resources through waste minimization, promotion of resource-use efficiency, and encouraging a move towards a circular economy. In addition, the strategy should ensure that damages caused to the natural environment are minimized and wastes are managed safely and carefully. Abdou showed that the kingdom is facing a massive increase in consumption, while the amount of natural resources has been decreasing.¹¹⁴ In this regard, the kingdom promotes the reuse of some types of household solid wastes. According to studies, waste reuse is the best option in the waste management hierarchy as a significant amount of energy is saved in not re-manufacturing the product.¹¹⁵

iii. Waste Landfill

Despite being the least desirable and sustainable approach to waste management, it is the most commonly used in KSA. Typically, landfills are used for non-hazardous wastes that meet certain predefined specifications through the application of techniques, which can assist in confining wastes to a small area as possible and ensure that compact waste is reduced in volume. A landfill site can be defined as a site where wastes are disposed of by burying.¹¹⁶ Landfills are mostly common in cities and urban areas. In these areas, landfills undergo a lifecycle that comprises of five phases. The first phase is the initial adjustment. At this phase, the wastes are

¹¹³Salman, Zafar, 1

¹¹⁴Abdou, M. H. "Health impacts on workers in landfill in Jeddah City, Saudi Arabia, 321

¹¹⁵Heister, R. E., and R. M. Harrison. Environmental and Health Impact of Solid Waste Management Activities. London: Royal Society of Chemistry, 2002, 44

¹¹⁶Abdou, M. H, 322

introduced into the landfill. Due to the high concentration of oxygen in landfills, microbial populations increase thus facilitating the biodegradation process. The second phase is the transition phase. At this phase, the high microbial population rapidly degrades the existing oxygen leading to more anaerobic conditions.¹¹⁷ As a result, oxygen is replaced by CO₂.

The third phase in the landfill involves acid formation. Acids are formed as a result of the hydrolysis of the biodegradable fraction of the solid waste leading to massive accumulation of volatile fatty acids (VFAs) in the leachate. The high concentration of VFAs enhances the concentrations of both the biochemical oxygen demand (BOD) and VOA, thus initiating the generation of hydrogen by fermentative bacteria.¹¹⁸ During this phase, metals, which are water-soluble at low pH, become more mobile leading to an increase in metal concentrations in the leachate. Phase four of the landfill lifecycle involves methane fermentation. At this stage, acid formation intermediary products, such as acetic, propionic, and butyric acids are converted into CH₄ and CO₂ by methanogenic microorganisms. Finally, the landfill reaches the phase of final maturation and stabilization. At this final phase, the rate of microbiological activities decreases as nutrients in the wastes become scarce and CH₄ production stops.¹¹⁹ Despite being commonly used, landfills can potentially lead to multiple issues, such as infrastructure damages, pollution of watercourses and other environmental factors.

Meanwhile, successful handling of the problem of wastes in emerging economies is bridled with numerous challenges. In Jeddah, wastes are buried in landfill sites that include holes dug in the ground and old quarries. In this approach, some wastes are expected to rot while

¹¹⁷Khalil, M. A, 344

¹¹⁸Nizami, Abdul-Sattar, 1

¹¹⁹Magram, Saleh F, 124

others in the process of decomposition will release methane gas, which is explosive and contribute to the greenhouse effect.¹²⁰ Poorly managed landfill sites can also attract vermin and results in the litter. Alternatively, incineration of wastes could also lead to problems as burning plastics produce toxic substances, such as dioxins.¹²¹ Gases generated during incineration lead to air pollution, which can also result in acid rains, while ash from incinerators could also contain heavy metals and other toxins.

To conserve material resources, studies show that Jeddah must minimize its reliance on landfills and address the environmental problems associated with this traditional waste handling initiative. Saudi Arabia must turn to the aggressive implementation of recycling and other waste reduction policies.¹²² In addition, studies propose some of the wastes that end up in landfills can be reused in households or as a resource in an industry. The problems faced by Jeddah's waste management approaches, such as limited areas for landfill, high costs of waste disposal, emission of greenhouse gases and dioxins, as well as concerns over health and environmental quality can be alleviated using proper management of wastes.¹²³ The government of KSA must, therefore, adopt an integrated waste management system based on the 3Rs (reduce, reuse and recycle). This approach ensures that there is an effective linkage between waste generation and resource consumption.

Though material by-products have been reused since the prehistoric times, modern technologies have led to an increase in quantity and complexity of what constitutes waste disposal streams. As a result, new technologies have exacerbated the waste management

¹²⁰ R. E. Heister and R. M. Harrison, *Environmental and Health Impact of Solid Waste Management Activities*, 26

¹²¹ Khalil, M. A. "Air quality in Yanbu, Saudi Arabia, 351

¹²² Magram, Saleh F, 125

¹²³ Abdou, M. H, 325

challenges faced by municipalities and government agencies. Proponents of resource-based paradigm in waste management suggest that waste materials should be viewed as potential resources; thus, waste reuse implies taking advantage of unexploited opportunities.¹²⁴ Besides, the use of end-of-waste criteria assists in the alleviation of prejudices related to waste labeling, thus encouraging waste reuse as a technical and environmental requirement. In this strategy, the reuse of metallic wastes is encouraged. By reusing non-biodegradable wastes, the environmental impact of waste disposal can be reduced significantly, especially in cities. Besides, the reuse of material resources does not only enhance the effectiveness of waste management but also support the livelihoods of thousands of people.¹²⁵

3.4 Economic and Environmental Impact of the Solid Waste in Jeddah

Solid waste disposal has massive environmental impacts, which could lead to various serious problems. In Jeddah, Saudi Arabia, wastes are largely disposed into landfill sites, i.e., holes in-ground or quarries while other sites are specially dug.¹²⁶ It is normally expected that wastes will eventually rot in these landfills. In the process, these wastes decompose to generate methane gas and which is explosive thus contributing to the greenhouse effect. Leachate produced in these landfills decomposes causing pollution.¹²⁷ The badly managed landfills in Jeddah may sometimes attract vermin and cause litter. In the industrial sector, incineration is one of the most common methods of waste management used. However, this approach also causes problems as plastic wastes produce toxic substances, such as dioxins, when burnt. Incineration involves burning of the solid waste which are first mixed thoroughly before being taken to the

¹²⁴Nizami, Abdul-Sattar, 1

¹²⁵Heister, R. E., and R. M. Harrison, 54

¹²⁶Abdou, M. H, 322

¹²⁷Anjum, Muzammil, et al, 25

combustion department.¹²⁸The gases produced from incineration may also cause pollution and contribute to acid rain while ash from the incinerators contains heavy metals and other toxins.¹²⁹ Due to these problems, there have been campaigns from around the globe against waste incineration. Therefore, the use of landfills as dumping sites and burning of the waste substances is economically overburdening to the country. It is because it will require the use of money to dig up holes and buying the machines used during the combustion process.

Poor management of solid wastes has a significant impact on the environment, economy, and even an individual's health and welfare. In general, waste management has considerable impacts on sustainability. On the environment, the conventional management practices of landfills Jeddah can cause several problems for the environment. For example, some types of wastes fail to rot leading to bad smell and generation of methane gas, which can be explosive or even cause respiratory problems. These gases also have a greenhouse effect. Poorly managed landfills can also attract vermin and cause litter, which can end up in water bodies, such as seas and oceans.¹³⁰ The use of incineration can also lead to air pollution as burning plastics produce toxic substances, such as dioxins. Incineration can also cause acid rain and heavy metals being released to the natural environment. Economically, the waste management practices in Saudi Arabia show that less than 30 percent of wastes are sorted. In this regard, plastics and other materials that can be reused and recycled are prematurely disposed of.¹³¹ This means an increase in energy expenditure in waste management as well as more costs in buying new materials.

¹²⁸Anjum, Muzammil, R. Miandad, M. Waqas, I. Ahmad, Z. O. A. Alafif, A. S. Aburiazaiza, and T. Akhtar. "Solid Waste Management in Saudi Arabia." *Applied Agriculture and Biotechnology* 1 (2016): 13-26.

¹²⁹Anjum, Muzammil, et al, 27

¹³⁰International Business Publications. Saudi Arabia Company Laws and Regulations Handbook. Int'l Business Publications, 2008, 17

¹³¹Gharaibeh, Emhaidy S., No'man M Haimour, and Bilal A Akash, 107

3.4.1 Impact on Air

Solid wastes and waste landfills have a huge impact on the environment. The effects of wastes are largely attributed and influenced by substances or chemicals, which are found in these wastes and the process of waste management.¹³² Though the existing data fails to link wastes to effects on human health and environment directly, it is evident the way wastes are managed as they enter the environment is crucial in the prevention of adverse health and environmental impacts of wastes. Studies show their numerous ways can negatively impact on the quality of air. Hazardous wastes and municipal solid waste can pollute the air.¹³³ Hazardous is defined as those wastes that, when released into the air has the potential to impact on human health and the environment negatively. Some of the common features of these wastes include ignitability, corrosivity, reactivity and toxicity.¹³⁴ Waste generation and management of hazardous wastes do not only lead to air contamination but can also contaminate land and water.

Municipal solid waste landfills are also the third-largest source of human-related methane emissions globally. It accounts for nearly 16 percent of all methane emissions.¹³⁵ Furthermore, decomposing wastes usually release dangerous gases, such as methane, CO, and CO₂ into the air¹³⁶. Some decomposing wastes also release Sulphur oxides to the air. Inhaling these gases can lead to respiratory problems to humans and other animals. Furthermore, poor management of wastes can easily lead to global warming or climate change problems. For instance, when heavy gases are released into the atmosphere, they deplete the ozone layer leading to an increase in

¹³²Abdou, M. H, 326

¹³³Abdou, M. H, 327

¹³⁴Anjum, Muzammil, et al, 28

¹³⁵Gharaibeh, Emhaidy S., No'man M Haimour, and Bilal A Akash, 108

¹³⁶ Martin F. Lemann, 64

temperatures. Baig et al. indicated that when paper and plastics are burned at the landfill, they cause various types of landfill gases and chemicals, which are released into the atmosphere.¹³⁷ These chemicals and gases accumulate and contribute to the depletion of the ozone layer. Besides, chemicals, such as dioxins when released to the air, are both harmful to humans and other living organisms. In this regard, improper management of wastes plays a significant role in global warming.¹³⁸

3.4.2 Impact on Water

Garbage has real impacts on the water just as other components of the environment. For instance, when wastes are released into landfills, chemicals in the trash can leech out into the soil, thus contaminating it.¹³⁹ The chemicals can have a significant impact on plants and even humans who come into contact with the soil. Once the soil is polluted, it becomes very difficult to clean the soil. Furthermore, chemicals do not just carry garbage into the soil but they also reach and contaminate the nearby surface water, such as rivers and lakes. These wastes lead to the destruction of water ecosystems and species, such as fish. Poor management of wastes can have an adverse impact on the quality and amounts of water available. Poorly managed solid and chemical wastes pollute and contaminate streams of water leading to negative impacts on both aquatic and human life.¹⁴⁰ Chemical wastes can be described as the harmful chemical by-products released from manufacturing facilities, laboratories as well as small scale chemicals from household and business items. In Saudi Arabia, some of the most common chemical wastes are used oil, asbestos, Sulphur, spent solvents, heavy metals, such as mercury, ethylene glycol,

¹³⁷Baig, Mirza B., et al., 5

¹³⁸Heister, R. E., and R. M. Harrison, 77

¹³⁹Hakami, Bader A., and El-Sayed Abu Seif, 6

¹⁴⁰Hakami, Bader A., and El-Sayed Abu Seif, 7

and so on. These chemicals are used in industrial, construction or processing sites.¹⁴¹ However, when exposed to rainwater, they can be washed into rivers, streams or lakes or directly into the soil. As a result, both surface and groundwater will be contaminated. Furthermore, when wastes are dumped next to a water source, they lead to a significant amount of water pollution as they are easily washed away into the water source. In addition, human wastes can facilitate the spread of dangerous bacteria if allowed to contaminate a water supply.

Elsewhere, solid wastes impact on the water quality through the release of leachate into water sources from landfills. When water comes into contact with decomposing solid waste, the waste dissolves, producing a polluted liquid known as leachate. As water seeps into the deeper layers of the landfill, the concentration of leachate also increases resulting in a light brown/black color of leachate, which also has a horrible stench.¹⁴² Leachate has a high potential to pollute water and cause harm to the living organisms in the water bodies since it has high concentrations of organic contaminants and high ammoniacal nitrogen. When leachate is discharged into water bodies, it can have an acute and chronic impact due to the presence of heavy metals. The concentration of heavy metals results in chronic toxin accumulation in organisms that depend on it and affect humans and animals that feed on these organisms.¹⁴³

3.4.3 Impact on Land

Improper disposal of wastes leads to serious problems on the land. Generally, landfill sites impact on the land as they leave holes on the grounds. In these landfills, some wastes will not rot, leading to an eyesore on the land. Poorly managed landfill sites can also attract vermin or

¹⁴¹Demirbas, Ayhan. "Optimization of municipal solid waste (MSW) disposal in Saudi Arabia.", 7

¹⁴²Baig, Mirza B., et al, 9

¹⁴³Abdou, M. H, 323

cause litter. Lightweight materials, such as plastic bags and film, can easily be dispersed from the landfills by wind or rain.¹⁴⁴ When left on open fields, these wastes present a wide range of harm to wildlife and domestic animals that can easily choke by confusing these materials for food. Chemical composition of plastics implies that it can take several years to breakdown when left on the land and also, they are capable of traveling long distances before fully decomposing. Currently, more than 80 percent of plastic litter found in oceans travelled from land as a result of being washed away by rain.¹⁴⁵ Landfills are also contribute to the release of gases which are generated from the decaying waste which have adverse effects on the health of people and causes air to be unfit for breathing. Moreover, the decaying materials release liquids that sip into the land causing the underground and surface water unfit for consumption.¹⁴⁶

3.4.4 Impact on Human Health

The majority of the human population around the world do not have access to a scientific waste management system. In this regard, a significant portion of the human population is at significant risk of various kinds of diseases, including respiratory issues and waterborne diseases.¹⁴⁷ Whether the wastes are accumulated in air, water or on land, landfill wastes have been found to cause cancer, create respiratory, and visibility problems, and so on. In addition, when a person comes into contact with wastes, he/she may suffer from skin irritation and blood infections.¹⁴⁸ Flies and other organisms at the landfill can also act as carriers of various illnesses,

¹⁴⁴Anjum, Muzammil, et al., 24

¹⁴⁵ Elizabeth M. Thomas-Hope, *Solid Waste Management: Critical Issues for Developing Countries* (Canoe Press, 1998), 22

¹⁴⁶ Alam, Pervez, and Kafeel Ahmade. "Impact of solid waste on health and the environment." *International Journal of Sustainable Development and Green Economics (IJSJDE)* 2, no. 1 (2013): 165-168.

¹⁴⁷"Vehicles, Air Pollution, and Human Health." Union of Concerned Scientists, www.ucsusa.org/clean-vehicles/vehicles-air-pollution-and-human-health

¹⁴⁸Demirbas, Ayhan, 8

such as malaria and dengue. Other diseases that these organisms can carry include Hantavirus Pulmonary Syndrome, Leptospirosis, Rat-bite Fever, and Salmonellosis, among others.¹⁴⁹

In 2012, air pollution was identified as one of the main causes of premature deaths around the world. Air pollution was found to be a significant risk factor for diseases, such as respiratory infections, heart diseases, COPD, lung cancer, and stroke, among others.¹⁵⁰ Studies indicate that when solid and small particle wastes are released into the air, humans and other animals risk inhaling these wastes through breathing, wheezing, and even ingestion.¹⁵¹ These processes can lead to conditions, such as asthma or worsen respiratory and cardiac conditions. The effect of releasing waste into the air is, therefore, increased use of medication, more hospital admissions, and early deaths. Individuals react to air pollutions depending on the type of pollutants they are exposed to. In the case of improper disposal of wastes in KSA's cities, people are exposed to pollutants, such as particulates, ozone, nitrogen dioxide, and sulfur dioxide, and so on.¹⁵² Children below five years are even more vulnerable to health conditions caused by these pollutants.¹⁵³

3.4.5 Impact on the Economy

Solid waste management is also an economic opportunity. That is, proper solid waste management can help in the generation of energy, recycling of materials and reuse of others. Therefore, waste management can be a source of revenue for cities, employment to the people

¹⁴⁹J.R. Balmes, J.M. Fine, D. Sheppard Symptomatic bronchoconstriction after short-term inhalation of sulphur dioxide *Am. Rev. Respir. Dis.*, 136 (1987), p. 1117

¹⁵⁰"Vehicles, Air Pollution, and Human Health

¹⁵¹"Vehicles, Air Pollution, and Human Health

¹⁵²Brimblecombe, Peter; Makra, László (2005). "Selections from the history of environmental pollution, with special attention to air pollution. Part 2*: From medieval times to the 19th century", 356

¹⁵³Abdou, M. H, 325

and improve energy efficiency.¹⁵⁴ In developing countries, such as Saudi Arabia, cities are the fastest-growing settlements. Cities have better services and create more employment. However, the rise of cities implies a significant increase in consumption and wastes in a small area. For cities to be attractive to people and investments, they must have proper waste management systems. Therefore, effective waste collection and disposal is one of the success factors in cities.

Solid waste materials can both have a positive and negative impact on the economy. Due to the increasing cost of raw materials and competition among firms, business leaders are increasingly turning to what was initially considered waste materials. More firms have adopted sustainability strategies involving reusing and recycling of raw materials.¹⁵⁵ Furthermore, recent research has found that the use of waste streams as feedstocks for energy and value-added products is increasing among firms. This approach can help municipalities and business entities to reduce waste-related environmental issues. In Saudi Arabia, recycling of metals and cardboard account for almost 15 percent of the total waste generated.¹⁵⁶ The recycling activities are mainly in the formal sector. Other products that can be recycled include glass bottles, aluminum cans, steel cans, plastic bottles, paper, cardboard, waste tire, etc.¹⁵⁷ From an economic perspective, waste products can be reused in the production process and also produce energy.

Funding is also a major barrier to waste management in Saudi Arabia. Jeddah has plans to modernize its waste management problem in line with the sustainability goals contained in the country's vision 2030.¹⁵⁸ These plans encompass awareness creation on proper waste

¹⁵⁴Efe, S. I. "Waste Disposal Problems and Management in Ughelli, Nigeria." *Journal of Environmental Protection* 4 (2013), 10

¹⁵⁵Hakami, Bader A., and El-Sayed Abu Seif, 3

¹⁵⁶Anjum, Muzammil, et al., 22

¹⁵⁷ Elizabeth M. Thomas-Hope, *Solid Waste Management: Critical Issues for Developing Countries*, 29

¹⁵⁸"Saudi Arabia's Vision 2030 Plan Is Too Big to Fail -- Or Succeed."

management, establishing sorting and recycling plants. To implement these plans around the country, a major injection of funds from the national government will be needed. Currently, there is a huge deficit of funds for the municipal authorities to address the waste management problem.¹⁵⁹ Furthermore, there is a lack of sufficient interest from the people and the private sector to invest more resources towards waste management.¹⁶⁰

¹⁵⁹Brimblecombe, Peter; Makra, László (2005). "Selections from the history of environmental pollution, with special attention to air pollution. Part 2*: From medieval times to the 19th century". *International Journal of Environment and Pollution*. 23 (4): 356. doi:10.1504/ijep.2005.007599.

¹⁶⁰Nizami, Abdul-Sattar

4 CURRENT LEGAL FRAMEWORK ON SOLID WASTE MANAGEMENT IN JEDDAH, KSA

4.1 Introduction

This section reviews various environmental standards and solid waste management regulations in KSA, which have considerable influence establishment and implementation of the current solid waste management system in Jeddah. This paper recognizes that the national and municipal government issues are addressed by most of the environmental laws in KSA. However, the municipal management of Jeddah city also enacts various regulations about the collection and disposal of solid wastes. Overall, both the national and municipal authorities share the responsibility of putting in place a working solid waste management system. The rest of this section examines current national laws and regulations on waste management, current municipal laws on waste management, national environmental standards, corporate regulations and powers of the solid waste management authorities.

4.2 Current National Laws and Regulations on solid waste management

Solid waste management is an important component of a country's national environmental policy. In general, environmental policies are designed to minimize environmental problems such as soil degradation, negative effects of slash and burn agricultural practices, water pollution from industrial refuse or wastes, threats to marine life populations, and groundwater contamination, among others.¹⁶¹ Specifically, the amount of solid wastes generated in Saudi Arabia has risen more than five times in the last decade alone. As a result, KSA has

¹⁶¹ IBP Inc, *Middle East and Arabic Countries Environmental Law Handbook Volume 1 Strategic Information and Regulations* (Morrisville: Lulu.com, 2015), 37.

urgently acted to develop a comprehensive environmental management framework to assist in measuring and monitoring economic, social, and physical activities, which could potentially hurt the environment.¹⁶² The comprehensive environment legal framework intends to ensure efficient use of natural resources, prevent depletion of resources and implement a sustainable development plan.

KSA has a comprehensive legal framework on solid waste management at the national level. The legal framework is established under the General Environmental Regulations and the Solid Waste Law, which outlines various responsibilities for waste management as well as the National Environmental Standards (NES).¹⁶³ In general, waste management legal framework is set out in line with various important principles of waste management, such as waste hierarchy, the duty of care, and proximity principle. The framework also provides clear guidelines for waste management in a manner that leads to the protection of human health and the environment. Some of the main responsibilities for the implementation of this legal framework include¹⁶⁴:

- i. The Presidency of Meteorology and Environment (PME) has the ultimate responsibility for environmental protection and waste regulation in the kingdom
- ii. The Ministry of Municipal and Rural Affairs (MOMRA) is responsible for strategic planning of waste management projects as well as delivery of municipal waste management services
- iii. Ministry of Health has responsibility for healthcare services and facilities

¹⁶² Nahed Taher and Bandar Hajjar, *Energy and Environment in Saudi Arabia: Concerns & Opportunities* (Springer Science & Business Media, 2013), 33

¹⁶³ *General Environmental Regulations And Rules for Implementation* (Kingdom of Saudi Arabia Presidency of Meteorology and Environment, n.d), 3

¹⁶⁴ *General Environmental Regulations And Rules for Implementation*, 7

- iv. The Saudi Industrial Property Authority (MODON) has the full responsibility for waste management of state-owned industrial cities

Saudi Arabia's legal framework on the environment is made of several standards and guidelines that help to the regulation of various environmental concerns, including air pollution, wastewater management, chemical transportation, and sustainability.¹⁶⁵ Specifically, solid waste management covers several standards and guidelines for environmental protection and management. In KSA, solid waste management activities are governed under various environmental laws at the national level. For instance, the kingdom adopted the Basic Law of Governance (Article 32), which stipulates that the state has a responsibility to preserve, protect and improve the environment while also designing and implementing measures intended to prevent pollution.¹⁶⁶ Furthermore, the state supports the Presidency of Meteorology and Environment (PME) with financial and technical resources so that they may be able to protect the environment effectively. According to PME, protection of the environment and mitigation of adverse weather conditions is a social, economic and moral responsibility that must be incorporated as part of the country's sound planning and development initiatives. PME draws its power from the General Environmental Regulation known as the Council of Ministers Resolution No. 193, which was enacted on September 24, 2001.¹⁶⁷

KSA also develops and implements its solid waste management policies in line with other international efforts or measures aimed at conserving the environment. For example, in 2007, the Kingdom supported OPEC by contributing USD 300 million towards the establishment

¹⁶⁵ Nahed Taher and Bandar Hajjar, *Energy and Environment in Saudi Arabia: Concerns & Opportunities*, 41

¹⁶⁶IBP. Saudi Arabia Mineral, Mining Sector Investment and Business Guide Volume 1 Strategic Information and Regulations, 38

¹⁶⁷IBP, 39

of the Research Fund for energy and environment.¹⁶⁸ In 2013, KSA endorsed United Nations Council Resolutions No. 692 and 786.¹⁶⁹ Nonetheless, there are several specific policies and procedures on environment health that one must adhere to in KSA. These policies ensure the protection of urban environments from the negative effects of solid wastes and other toxic chemicals.¹⁷⁰ KSA has also established the National Environmental Awareness and Sustainable Development Program aimed at making the country green. In this program, the national agencies are expected to partner with NGOs, private sector, and international organizations, such as UNDP towards the development of a well-educated society in the area of environmental protection in the kingdom. Some of the short-term objectives of the program included to promote environmental awareness of the people regarding local, regional and international issues and build a strong relationship between environmental sustainability and economic development, develop comprehensive procedures, which can address various environmental problems and adopt activities that can help in nurturing of environment-friendly behaviors.¹⁷¹

In the long-term, the National Environmental Awareness and Sustainable Development Program aimed at reinforcing environment-friendly behaviors, which can promote sustainable development and ensure that public institutions enforce existing environmental standards and enact laws that can lead to an improved quality of the environment. In this case, the program was classified into key pillars of (1) personal hygiene, (2) environmental management of solid waste, (3) climate change and effects of air pollution, (4) maritime and coastal environment, (5) promote sustainable consumption patterns, (6) conserve natural resources and (7) health and

¹⁶⁸ P. Vincent, *Saudi Arabia: An Environmental Overview* (Boca Raton, FL: CRC Press, 2008), 29

¹⁶⁹ Allain, Jean. *International law in the Middle East: closer to power than justice*. Ashgate Publishing, Ltd. 2004. 159

¹⁷⁰ IBP Inc, 57.

¹⁷¹ Nahed Taher and Bandar Hajjar, 41

environment.¹⁷² Solid waste management laws are also set to protect the kingdom's biological diversity and sanctuaries. This environmental law acknowledges that Saudi Arabia's geological formation includes two regions, i.e., Euro-Asian and African-Equatorial, thus making the country to be of great ecological significance.¹⁷³ Due to this, Saudi Arabia's environmental policies consist of multiple measures aimed at protecting biological diversity in the Kingdom and maintaining wildlife habitats, as highlighted in the General Environmental Regulations and Rules for Implementation.¹⁷⁴

Saudi Arabia is one of the leading countries in the Middle East for environmental conservation, especially in relation to solid waste management. In this regard, the kingdom has adopted several regulations, which show that it is ready to take environmental issues more seriously. These regulations include the National Ambient Water Quality Standard of 2012, Wastewater Discharge Standard of 2012, Standard on Waste Transportation 2012, and Standard on Waste Transportation 2012, among others.¹⁷⁵ The National Ambient Water Quality Standard of 2012 provides a framework for sustainable management of ambient water quality and offer protection to water quality and the natural aquatic environment. This standard is to be applied for the case of all forms of coastal, underground, and surface freshwater, which is either present permanently or temporarily.¹⁷⁶

Wastewater Discharge Standard 2012 was formulated and implemented to target various companies and people, which discharge wastewater. The Wastewater Discharge Standard of

¹⁷² IBP Inc, 61

¹⁷³ P. Vincent, *Saudi Arabia: An Environmental Overview* (Boca Raton, FL: CRC Press, 2008), 38

¹⁷⁴ See appendix of the *General Environmental Regulations And Rules for Implementation*

¹⁷⁵ Energy and Environment in Saudi Arabia: Concerns & Opportunities, 87

¹⁷⁶ Energy and Environment in Saudi Arabia: Concerns & Opportunities, 88

2012 provides a guide through which Saudi Arabia can attain its ambient water quality objectives.¹⁷⁷ The standard designed criteria and specific limits governing individual discharges aimed at protecting water quality.¹⁷⁸ The overall objective of the standard is to ensure efficient wastewater management in KSA.

Additionally, the Technical Guidelines of 2012 on the Prevention of Major Accidents stipulates that activities that involve manufacturing, processing, using, storing and handling of dangerous substances were required to take necessary steps to prevent accidents, which could lead to the release of toxic or flammable materials into the environment.¹⁷⁹ This standard also applied to activities, which could potentially lead to fires, explosions, structural failures and any other accident that involve dangerous materials. Moreover, the standard intends to ensure that accidents, which could lead to the release of dangerous substances into the environment are reduced and prevented.¹⁸⁰

The Environmental Standards on Material Recovery and Recycling of Waste 2012 also applies to all companies that operate in KSA. This standard explains how these companies should dispose of and treat the wastes that they generate.¹⁸¹ This standard forms an integral part of the guideline on waste management issued by the Presidency of Meteorology and Environment, whose primary goal was to ensure that the best environmental practices on waste recovery and recycling are developed and implemented in all industrial sectors within the Kingdom. The document was developed based on the universally recognized waste management

¹⁷⁷Chakibi, Sanaa. "Saudi Arabia Releases 9 New Environmental Laws." EHS Journal, January 2013

¹⁷⁸Chakibi, Sanaa, 1

¹⁷⁹General Environmental Regulations And Rules for Implementation, 5

¹⁸⁰General Environmental Regulations And Rules for Implementation, 6

¹⁸¹General Environmental Regulations And Rules for Implementation, 6

hierarchy consisting of waste prevention, waste recycling, waste treatment and waste disposal.¹⁸² It required specific participants in various industries to implement the most sustainable measures in line with the hierarchy. In the meantime, the Biological Treatment Standard of 2012 was enacted to ensure compliance with a series of design, location, operation, and closure requirements for biological treatment and incineration facilities.¹⁸³ This standard stipulates various requirements in relation to the treatment and disposal of biodegradable waste. These requirements also apply to the development of new biological treatment facilities, which target the collection and handling of biodegradable wastes. The standard also sets parameters for facility design and operations in the kingdom.¹⁸⁴ However, the standard exempted domestic biological process, such as composting from adhering to the strict requirements.

The Standard on Waste Transportation 2012 also governs solid waste management in Saudi Arabia. This standard highlights that hazardous, and non-hazardous transporters must comply with an updated Framework for Waste Transportation in Saudi Arabia.¹⁸⁵ The Presidency of Metrology and Environment adopted the Standard on Waste Transportation to act as a guide to monitoring and controlling waste movement as well as protection of both human health and the environment. This standard also provides a framework used to classify and label wastes thus facilitating the movement of wastes and dangerous goods within and outside the country. This standard also expects companies operating within the kingdom to comply with the provided labeling and classification requirements in relation to transportation of wastes, vehicle safety, and documentation of the waste transported as well as training and certification of the

¹⁸²General Environmental Regulations And Rules for Implementation, 7

¹⁸³General Environmental Regulations And Rules for Implementation, 8

¹⁸⁴General Environmental Regulations And Rules for Implementation, 9

¹⁸⁵Faisal K. Alturki, 29

drivers.¹⁸⁶ The primary objective of these requirements is to minimize road accidents associated with waste transporters and provide waste transporters with a consistent system of waste labeling and classification.¹⁸⁷

Current laws regarding environmental protection in Saudi Arabia are linked to key economic sectors in the kingdom, among them the production, processing and the manner in which oil and natural gas is transported.¹⁸⁸ The laws only need to be shifted to fit the solid waste water management context. Wastewater and biological treatment standards and the laws and regulations that are used in the country apply to companies and organizations charged with taking care of the environment.

4.3 Current Municipal Laws on Solid Waste Management in Jeddah

Municipalities in the Kingdom of Saudi Arabia are required to adhere to the national environmental laws as well as regulations and guidelines as set out by PME. The industries that register with municipalities, for example, are imposed by strict rules of the Saudi government. The rules the national government sets for their monitoring are meant to protect the environment, explaining why heavy penalties are imposed if they do not adhere to any of them in their municipalities, Jeddah for example. Specific states have their laws or codes governing solid waste management.¹⁸⁹ Laws ensure that there is the sufficient education of all Jeddah residents and companies in particular to have them gain awareness that they need to support the formation of programs that show just how committed the city is to cleaning the environment through the

¹⁸⁶Chakibi, Sanaa, 1

¹⁸⁷General Environmental Regulations And Rules for Implementation, 11

¹⁸⁸ Ibid, 180

¹⁸⁹Taher, Nahed, and Bandar Hajjar. *Energy and Environment in Saudi Arabia: Concerns & Opportunities*. Berlin: Springer Science & Business Media, 2013, 61

implementation of solid waste management procedures and processes. The Ministry of Municipality and Rural Affairs assists the Jeddah authorities with urban solid waste management in a similar manner to how they help with the management and disposal of wastewater and the cleaning of the city and town. The functioning of these ministries is faced with the problem of overlapping and multiple jurisdictions in their areas of engagement, calling for the proposed changes in the laws governing solid waste management in Jeddah covered. The ministries lack the guidance on the management and coordination of their responsibilities in the multiple jurisdictions calling for Jeddah's authorities to come in with their own laws, or with revised versions of the current ones.¹⁹⁰ However, despite their focus on passing and enforcing municipal laws on solid waste management, they are faced with problems for the waste management system they follow lacks complete jurisdiction over the entire activity, even in Jeddah. Informal sectors, for instance, carry out more than 25% of the municipal's and kingdom's waste management. It does not mean that the municipal and national governments do not coordinate and finance the efforts. It further explains why, since the Jeddah Strategic Plan 2009, the city's government decided to pursue partnerships with the private sector in handling waste management.¹⁹¹ The current efforts because of the laws passed and enforced are yet to meet the municipal's demands for solid waste management, but their efforts have gained serious attention.

Among the reasons for pursuing partnerships with private sector in waste management are the costs involved in the process of solid waste management. The cost reduction needs by the city's authorities drives the municipal laws it passes guiding solid waste management. The environmental laws are based on the Islamic Sharia law, the main source of law in Saudi Arabia,

¹⁹⁰ Ibid, 75

¹⁹¹ Oxford Business Group, 120

also meaning that Jeddah's environmental laws and regulations, even the proposed ones, are supposed to be in line with the current Sharia laws. This is what separates the proposed environmental laws and regulations to guide in the implementation of working solid waste management policies from the mostly international ones.

Comparative law methodology is applicable to the context that phrases the national and municipal laws in Jeddah. Comparative law methodology could be more applicable when discussing the scientific relevant context of the new laws and regulations that should guide Jeddah's waste management improvements. Just looking at having Jeddah's law change minus the new eye, from a new perspective and at some distance means sticking to the very current context. However, comparative law is supposed to come in to help look at the perspectives that could apply for Jeddah that are currently not doing so and that might not get to do so if and when the law is said to only be considered from the Sharia-law circles and context. What makes it likely to discuss changes to the current municipal laws on solid waste management in Jeddah with the comparative law in mind is that there is the perspective of the functioning of different legal systems, some of which are currently beneficial where they are applied.¹⁹² However, there is a change in the way of looking at the comparative law, as they have to be considered in the Saudi Arabian context. Some of them may not be properly fit for the current laws that are applied in solid waste management in Jeddah, so they are either to be left out or phrased to the proper fit and to according to the context.

¹⁹² Darpo and Nilsson, 10

In addition, municipal laws are designed based on the conservation tenets of "reduce, reuse, and recycle."¹⁹³ Furthermore, other municipal laws, such as in Riyadh and Jeddah also aim at aggressive community sensitization and enlightening of the consumers regarding various reduction methods. In Jeddah, a solid waste management system involves the collection of wastes from bins, which are scattered all around residential and commercial areas in the city. After collection, the wastes are sent to the transfer stations where they ultimately end up at Buraiman or (Almusk) Lake dumping site.¹⁹⁴ The use of this traditional waste management approach shows that waste management is still a major challenge that even the most developed cities in KSA are yet to address amicably. In most of these cities, the municipal laws grant the responsibility of solid waste collection and disposal to various agencies with the municipal authority acting as the oversight body. In recent years, various cities have changed their approach to waste management.¹⁹⁵ For instance, these cities also aim at alleviating waste management challenges through the creation of economic and employment opportunities by encouraging investments in waste-to-energy (WTE) and waste to recycling facilities.

Solid waste management regulations in Jeddah are relatively similar to those set in other major KSA cities such as Riyadh, Jubail, and Yanbu. Nevertheless, studies indicated that city management authority in Jeddah is lagging in the development and enforcement of new regulations that would improve the collection and treatment of solid wastes¹⁹⁶. Compared to the three other major cities, Jeddah is yet to develop and enforce a comprehensive sustainable solid waste management strategy. In 2016, Riyadh became the first major city in Saudi Arabia to

¹⁹³Energy and Environment in Saudi Arabia: Concerns & Opportunities. Berlin: Springer Science & Business Media, 2013, 61

¹⁹⁴ P. Vincent, *Saudi Arabia: An Environmental Overview*, 44

¹⁹⁵ P. Vincent, 48

¹⁹⁶ P. Vincent, 49

adopt a comprehensive solid waste management strategy backed by a modern legal framework. The strategy was developed by the ArRiyadh Development Authority (ADA) for the High Commission for the Development of ArRiyadh.¹⁹⁷ The strategy leverages partnerships with several key stakeholders in the city to develop a strong coalition for the city's waste management vision. The city authority provides leadership on waste management and suggests measures that can lead to management of the city's waste as a resource while protecting human health and the environment. The city aims to significantly minimize the quantity of waste produced by encouraging and implementing the best technologies in the treatment and recovery of value from waste. This new waste management approach in Riyadh clearly defines the roles and responsibilities of various stakeholders as well as proactive partnership between the government and business.¹⁹⁸ Riyadh strategy was set out in line with the kingdom's vision 2030 that supports the total diversion of solid waste management from landfills to material recovery facilities to produce renewable energy and recycling.¹⁹⁹

On the other hand, the Royal Commission for the industrial cities of Jubail and Yanbu issued comprehensive local environmental regulations, which apply to all facilities and economic activities within the Royal Commission areas.²⁰⁰ For instance, the regulations stipulate what is required of contractors operating in these industrial cities in relation to waste disposal. Unfortunately, even in cities with a comprehensive regulatory framework, the implementation of these strategies remains a major challenge. For example, in Riyadh, the regulatory requirements

¹⁹⁷ High Commission for the Development of Riyadh, *Comprehensive Waste Management Strategy for ArRiyadh City* (2016), 17, <http://www.arriyadhenv.gov.sa/wp-content/uploads/2016/12>

¹⁹⁸ High Commission for the Development of Riyadh, *Comprehensive Waste Management Strategy for ArRiyadh City*, 21

¹⁹⁹ High Commission for the Development of Riyadh, 17

²⁰⁰ *Ibid*, 75 16

are not strictly enforced.²⁰¹ Due to this, there are high rates of corruption in the waste management sector leading to widespread illegal tipping and dumping. There is poor compliance with various waste acceptances, classification and tracking systems, which are the main requirements of NES 8, 9, and 12. Furthermore, effective regulation of waste management in many cities is hindered by the uncertainties regarding the dumping sites. In addition, Al-Ahsa's waste management approaches do not coincide with the principles of the waste hierarchy, proximity, duty of care and best practical environmental option as required under NES 18.²⁰² Gharaibeh, Haimour and Akash argued that this situation is facilitated by the lack of public awareness on the legal requirements in waste management in Saudi Arabia.²⁰³ There are regulatory tools applied in sector management in Jeddah that require licenses and controls to be applied to the waste management techniques currently used. Cities in Saudi Arabia apply their own particular laws, a good example being the cities of Yanbul and Jubail, which currently have their own Royal Commission Environmental Regulations' volumes. It, therefore, means that Jeddah's law requirements could be their own, but within the Royal Commission Environmental Regulations. The limitations of the extent of laws and regulations in Saudi Arabia, despite being limited, can only be adopted on an ad-hoc basis by Jeddah's authorities, but it is possible to sign, enforce, and implement laws based on international agreements and treaties that are concerned with environmental matters. They would become extensions of the current Saudi Arabian regulations.

²⁰¹ Emhaidy S Gharaibeh, No'man M Haimour, and Bilal A Akash, "Evaluation of Current Municipal Solid Waste Practice and Management for Al-Ahsa, Saudi Arabia," *Int. J. of Sustainable Water and Environmental System* 2, no. 2 (2011), 105

²⁰² Emhaidy S Gharaibeh, No'man M Haimour, and Bilal A Akash, "Evaluation of Current Municipal Solid Waste Practice and Management for Al-Ahsa, Saudi Arabia," 106

²⁰³ Emhaidy S Gharaibeh, No'man M Haimour, and Bilal A Akash, 107

4.4 Corporate Regulations for Drilling Operations in Saudi Arabia

Drilling is one of the main sources of solid wastes in Saudi Arabia. As an Islamic state guided by Shariah laws, KSA administration expects companies in the oil sector to adopt and implement effective environmental policies and regulations, which can lead to effective solid waste management. The government expects them to have the state of the environment before and after drilling procedures in mind. For instance, KSA's national oil company, Saudi Aramco, is given full authorities to determine, formulate and implement corporate regulations governing drilling operations in the kingdom.²⁰⁴ The national oil company also invests in petrochemicals. In this regard, Saudi Aramco plays an important role as the country attempts to establish environmental credibility when joining the collective global action without countering the specific economic interests in the country beyond the age of oil.²⁰⁵ As a matter of national policy, Saudi Arabia does not import or export natural gas. Therefore, corporate regulations targeting natural gas must aim at self-sufficiency and efficient allocation of natural gas to domestic customers. The regulations also determine quotas to allocate for the consuming sectors, including power producers and industrial firms, such as those involved in the production of glass, aluminum, fertilizer or other petrochemicals.²⁰⁶ Saudi Aramco is, therefore, tasked with the reduction of gas supply constraints by investing heavily in the development of associated gas fields.²⁰⁷

²⁰⁴ Mohamed A. Ramady, *Saudi Aramco 2030: Post IPO challenges* (Basingstoke: Springer, 2017), 22

²⁰⁵ *Saudi Aramco: Saudi Aramco Residential Camp in Dhahran, Saudi Aramco, Abqaiq, Ras Tanura, Dhahran Airfield, Ghawar Field, Udhailiyah* (Books LLC, Wiki Series, 2010), 19

²⁰⁶ *Saudi Aramco: Saudi Aramco Residential Camp in Dhahran, Saudi Aramco, Abqaiq, Ras Tanura, Dhahran Airfield, Ghawar Field, Udhailiyah*, 33

²⁰⁷ Mohamed A. Ramady, *Saudi Aramco 2030: Post IPO challenges*, 29

Saudi Aramco has always been concerned about environmental issues even before the regulations were introduced. This is illustrated in the Company codes and standards, which are aimed at monitoring, regulating, and controlling industrial operations so as to reduce the effect on the environment.²⁰⁸ These codes and standards also apply to contractors who work with the company. For instance, Saudi Aramco ensures that strong corporate standards and guidelines are always incorporated as core elements of its environmental policy. With this, the company's objective is to manage its operations across the kingdom without adverse impacts on the environment. This objective is well entrenched in the company's engineering standards, codes, and departmental procedures, which are consistent with the national regulations and guidelines.²⁰⁹ These standards apply to both offshore and onshore drilling operations. Specifically, Saudi Aramco has comprehensive environmental regulations regarding offshore operations.²¹⁰ Some of the current drilling operations are carried out using methods meant to be less environmentally destructive, a good example being the company's directing of the drill-it in the subsurface from a centralized location even miles away from the drill site, and then transmitting data about it via satellite to make real-time activity possible. By doing this, the company is precise and almost always on the mark about where to carry out their drilling. The accuracy associated with this geosteering results in lighter footprint and it boosts the sustainability factor of natural gas which emits low carbon dioxide levels. At the same time, the requirement that Saudi Aramco apply this means to drilling ensures that there is less environmental destruction on the ground, especially because there are less target zones and less

²⁰⁸International Business Publications. Saudi Arabia Company Laws and Regulations Handbook. Int'l Business Publications, 2008, 12

²⁰⁹International Business Publications. Saudi Arabia Company Laws and Regulations Handbook, 15

²¹⁰*Saudi Aramco: Saudi Aramco Residential Camp in Dhahran, Saudi Aramco, Abqaiq, Ras Tanura, Dhahran Airfield, Ghawar Field, Udhailiyah* (Books LLC, Wiki Series, 2010), 17

driving back and forth, which means that there are less drilled zones and less solid waste in and around the target zones.²¹¹

Furthermore, the Regulations with detailed requirements for facilities and activities that the General Authority for Meteorology and Environmental Protection (GAMEP) is supposed to implement and oversee include guidelines on effective land use and urban development. Saudi Aramco, a company that operates tens of thousands of pipeline network carries out their construction following specific guidelines and regulations in line with environmentally sustainable technical specifications. Among the considerations include the design factor of the pipelines being based on area classification and population concentration. These are guidelines to the benefit of a city with millions of people like Jeddah because it considers how the city will manage solid waste in the case the company constructs its pipeline network without some of these considerations at hand. Important things to note like the construction of emergency isolation valves at the ends of any pipeline minimize the possibility for emergencies causing destruction in the form of solid waste. The environmental impact assessments (EIA) that GAMEP has Saudi Aramco conduct keep the drilling procedures in check. Appendix 4 of the Executive Regulations of the General Environmental Law govern the principles as well as the procedures for Saudi Aramco's control of dangerous solid waste by prohibiting the company from putting in place projects that may result in the production of excess waste, especially at a time when there's the focus at how to expand the bounds of a city like Jeddah to hold the ever-growing population.²¹² The regulations for the trading part of petroleum are enforced under the

²¹¹ Ali, Sadaqat, Roger Sung, and Abdul Mohsen Al-Maskeen. "Horizontal Well Correlation Using Real Time Data and Log Prediction in Geosteering Complex Reservoirs of Saudi Arabia." *18th Middle East Oil & Gas Show and Conference (MEOS)*. 2013.

²¹² Goswami, *Oil and gas regulation in Saudi Arabia: Overview*. Thomson Reuters Practical Law.

Article 17 (1) of the General Environmental Regulations have GAMEP be certain that no traders in petroleum violate laws that require them to remove or steer clear of procedures and processes with negative environmental impact, under which the guidelines on how they manage solid waste in and out of the drilling fields fall.

Offshore operations regulations apply to activities that use vessels, such as drilling rigs, supply boats, barges, and so on while working on the territorial waters of KSA or working with various Saudi contractors.²¹³ Regarding sewage disposal, offshore operators are required to establish a sewage treatment plant if their facility is located less than four nautical miles from land. Ten or more people should operate the treatment plant. Discharge effluents must meet all the requirements in the General Environmental Regulations and Rules for Implementation guidelines and standards for organic, non-organic and chemical pollutants.²¹⁴ In addition, the offshore operator must ensure that all types of water flows, including surface run-off/effluent and oil drainage, are collected using sealed systems. The disposal of treated and untreated effluent should adhere to the standards set in the Wastewater Discharge Standard 2012.²¹⁵ These operators are also required to haul back to the land or onshore disposal site all oil-based drilling fluids, toxic fluids and cuttings from the toxic drilling fluids. LC-50 toxicity tests must be conducted for all alternative oil-based fluids.²¹⁶ The tests are intended to determine the toxicity of the cuttings. The toxicity levels help to determine which cuttings should be disposed of.²¹⁷

²¹³Krane, Jim. *Energy governance in Saudi Arabia: An assessment of the Kingdom's resources, policies and climate approach*. Center for Energy Studies, 2019, 4

²¹⁴*General Environmental Regulations And Rules for Implementation*, 6

²¹⁵*General Environmental Regulations And Rules for Implementation*, 8

²¹⁶Krane, Jim. *Energy governance in Saudi Arabia: An assessment of the Kingdom's resources, policies and climate approach*, 6

²¹⁷Krane, Jim, 7

Elsewhere, in the last decade, the KSA administration has been attempting to improve the economic, social, and environmental sustainability of various activities in the kingdom from oil extraction to solid waste management. Under the sustainability strategy, several regulations have been developed.²¹⁸ These regulations touch on areas of discharges to the marine environment from drilling operations, wastewater treatment re-use and disposal, protection of marine life, pollution control and environment protection and waste management for mud, cuttings and rubbish, and so on. The sustainable model ensures that every business operation in Saudi Arabia is promoting sustainable living by using sustainable means of production of goods and services and providing solutions that fulfill elementary people's needs to improve the quality of their lives.²¹⁹ KSA's sustainability strategy is meant to ensure that industrial and oil production practices include waste management approaches that are conducted in a manner that leads to the least possible environmental impact and highest levels of economic and social benefits.²²⁰ In general, sustainability is about availing resources and opportunities to the current generation without hampering the ability of future generations to satisfy their needs. The goal of KSA's corporate sustainability strategy is to ensure that the entire economic system in the country facilitates people's welfare.²²¹

The primary catalyst of Saudi Arabia's sustainability strategy is the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC), which she is a signatory. The Kyoto Protocol placed legislative pressures on sovereign nations to reduce their

²¹⁸ M. A. Hashmi, N. Abdulghaffar, and I. Edinat, "Sustainability Commitment In Saudi Arabia And Need For Educational Reforms For The Jobs Of The Future," *International Business & Economics Research Journal* 14, no. 1 (2015), 5

²¹⁹ Krane, Jim, 10

²²⁰ M. A. Hashmi, N. Abdulghaffar, and I. Edinat, "Sustainability Commitment In Saudi Arabia And Need For Educational Reforms For The Jobs Of The Future, 7

²²¹ M. A. Hashmi, N. Abdulghaffar, and I. Edinat, 10

greenhouse gas emissions. Saudi Arabia being one of the world's emitters of greenhouse gases due to its huge oil and gas industry and expanding the petrochemical sector, has, therefore, bound to act appropriately. Saudi Arabia responded to the demands of the Kyoto Protocol by enacting a raft of environmental standards. The Meteorology and Environmental Protection Administration (MEPA) was established as the agency tasked with pollution regulation and controls as well as addressing other environmental matters.²²² MEPA issued several environmental standards and guidelines with others targeting various corporations operating in the oil drilling industry. The regulations targeting corporations in the oil drilling sector included those aimed at ensuring ambient air quality, controlling air pollution sources, water management guidelines and discharge performance. Most of the legislations on MEPA activities are found under the General Environmental Regulation (Royal Decree No. M/34 dated 28/7/1422H, corresponding to 15/10/2001). Saudi Arabia also approved the General Environmental Regulation for the GCC and the Environmental Assessment Regulation for the GCC. These regulations largely target the participants in the oil and gas drilling.²²³ For example, the two regulations prohibited actions or acts of omissions that can lead to adverse effects on the environment. In this regard, oil drilling companies are required to put in place precautionary and pre-emptive measures that can ensure the adverse effects do not occur and projects, which are at high risk of leading to adverse environmental effects are avoided.²²⁴

²²²*General Environmental Regulations And Rules for Implementation, 2*

²²³Krane, Jim, 12

²²⁴*General Environmental Regulations And Rules for Implementation, 4*

4.5 Environmental Regulations on Offshore Operations such as Sewage Disposal, Industrial Drainage

Saudi Arabia's environmental regulations governing drilling operations apply to all vessels, such as drilling rigs, supply boats, barges working in Saudi territorial waters, or working under Saudi Aramco contractors in offshore areas.²²⁵ These regulations govern sewage disposal, industry drainage, and trash disposal, and so on. Regarding sewage disposal, the vessels must have a sewage treatment plant within four nautical miles from land, and ten or more people should operate the plant. The discharge effluent must also meet requirements for organic/non-organic and chemical wastes. On industrial drainage, the regulation stipulates that all types of water flows include surface run-off and oil drainage should be collected using sealed systems to slop tanks or caissons.²²⁶ Furthermore, no discharge is allowed into the sea and the disposal should be taken back to a nearby approved onshore disposal site. In addition, oil-based drilling fluids and cuttings from toxic drilling fluids must also be taken back to an approved onshore disposal site.

General Environmental Regulation demands that companies engaged in offshore operations should voluntarily engage in the integration of social and environmental measures that can lead to the sustainability of operations. The environmental policy also demands integration among stakeholders. Due to this regulation, organizations in this sector have responded in various ways, including compliance with the ISO 14001 certification and environmental responsibility.²²⁷ This standard encompasses various measures needed to ensure corporate

²²⁵International Business Publications, 22

²²⁶Taher, Nahed, and Bandar Hajjar, 55

²²⁷Krane, Jim. *Energy governance in Saudi Arabia: An assessment of the Kingdom's resources, policies and climate approach*, 14

environmental performance and behavior. It also offers an environmental accounting model that outlines the process of achieving and maintaining a sustainable environment. These actions target mitigation, resource management, enforcement, education, and social responses that can effectively address environmental challenges, such as oil spillages. Overall, Saudi Arabia's environmental regulatory framework provides a platform for the government and organization to protect the environment and prevent pollution generated by various offshore activities.²²⁸ The regulatory framework also provides a guideline to protect public health against the dangers of offshore activities and other adverse actions on the environment and conservation efforts.

Several rules govern foreign investments in various sectors of the Saudi economy. According to Foreign Investment Law (Royal Decree No. M/1 dated 5/1/1421H, corresponding to 10/4/2000), all firms operating in KSA with foreign shareholders must obtain a foreign capital license issued by the Saudi Arabian General Investment Authority (SAGIA).²²⁹ General Environmental Regulation framework also encourages partnerships in areas of addressing the environmental dangers of offshore operations. For instance, in a bid to increase the environmental awareness among children of pollution and dangers of offshore operations, the government partnered with the United States through the Global Learning and Observations to Benefit the Environment (GLOBE) program. The primary objective of the program is to enhance international awareness of environmental issues through education and technological applications. The program offers training and supplies various instruction tools to schools in both

²²⁸*General Environmental Regulations And Rules for Implementation, 5*

²²⁹Krane, Jim, 19

the United States and Saudi Arabia.²³⁰ The program recognizes that students are exposed to various complexities of environmental issues, especially from globalized economic activities.²³¹

4.6 Current enforcement procedures by General Environmental Regulations

PME's primary objective is to ensure that all environmental regulations are enforced. The environmental legislation outlined a wide range of prohibitions on pollution and contamination of land, water, and air in relation to various economic activities. Project owners were expected to comply with existing and future environmental specifications, standards, measurements, and guidelines as stipulated by the PME.²³² PME also set out guidelines on how the rules were to be implemented. For example, before starting a project in Saudi Arabia, an environmental assessment study must be conducted and approved by the PME. The details on how these legislations operate are contained in the appendices of the Implementing Rules, including the Environmental Protection Standards, Procedures for the Assessment of Environmental Effects of Industrial and Development Projects, Manual of Environmental Qualification Procedures, Rules and Procedures for the Control of Hazardous Waste, National Contingency Plan for Combatting Pollution by Oil and other Harmful Substances of the Marine Environment in Emergency Cases, and Violations and Fines. PME also enforces General Environmental Regulations in a manner that is consistent with the Sustainable Development Goals 2014.²³³ That is, PME also prioritizes education and training of stakeholders and citizens on environmental protection to enhance the

²³⁰*General Environmental Regulations And Rules for Implementation*, 22

²³¹See "GLOBE Program," website: <https://www.globe.gov/about/overview>.

²³²Faisal K. Alturki, 38

²³³Taher, Nahed, and Bandar Hajjar, 69

effectiveness of environmental management and implement modern procedures that ensure compliance of the Kingdom's environmental laws.

In general, the General Environmental Regulations and Its Rules for Implementation are designed and implemented to achieve the following objectives:²³⁴

- i. Preservation, protection, and development of the environment in a manner that prevents its pollution
- ii. Protection of public health from activities that could harm people's environments
- iii. Conservation and development of natural resources in a rational manner
- iv. Ensuring environmental planning forms key components of development plans
- v. Raising awareness of the environmental issues and strengthening individual and collective feeling of responsibility towards preservation and improvement of the environment

To attain these objectives, a competent agency, i.e., PME was formed to execute all the duties intended at the preservation of the environment and prevention of deleterious effects of various activities.²³⁵ The agency is tasked with the review and evaluation of the environmental conditions and development of monitoring tools. The agency also collects and conducts environmental studies to ensure that natural resources are not only used efficiently but are used in a manner that conserves the environment. The agency documents and publishes environmental information as well as preparing, issuing, reviewing, developing and interpreting environmental protection standards.²³⁶ Furthermore, the agency proposes environment regulations, which are

²³⁴*General Environmental Regulations And Rules for Implementation,7*

²³⁵*General Environmental Regulations And Rules for Implementation,7*

²³⁶*General Environmental Regulations And Rules for Implementation,8*

relevant for every jurisdiction and ensure that all the public agencies and individuals involved are compliant to the environmental regulations, criteria and standards, and also coordinate with the licensing agencies.

General Environmental Regulations and Its Rules for Implementation requires all public agencies to take necessary actions in applying the rules set for their projects or activities under their supervision and licensing.²³⁷ Public agencies must be committed to the effective implementation of all environmental regulations, criteria, and standards as stated in the rules for implementation. Public agencies must coordinate with the PME before issuing standards, specifications, and rules relating to various practices that have an impact on the environment. Consequently, licensing agencies should ascertain that the environmental studies conducted for various projects, which could potentially harm the environment has been done at the project feasibility stage and the agency tasked with the project implementation of the project must conduct the environmental assessment studies in line with various environmental basics and standards as determined by the PME under the rules for implementation.²³⁸ Besides, the agency implementing the new projects or modifying the existing projects must use the best and most suitable technologies, which are available within the local environment and could cause the least negative impact on the environment.

The regulations also emphasize the creation of awareness for environmental protection. For instance, all agencies within the education sector must include environmental concepts in the curricula at various stages of education. All agencies in-charge of media should also strive to improve environmental awareness through the use of various mass media and support the

²³⁷*General Environmental Regulations And Rules for Implementation, 12*

²³⁸*General Environmental Regulations And Rules for Implementation, 14*

concept of environmental protection from an Islamic perspective.²³⁹ The agencies in-charge of Islamic affairs and guidance should enhance the role of mosques in encouraging the community to preserve and protect the environment. All the stakeholders in environmental awareness creation should prepare appropriate training programs, which will lead to the development of capabilities in the field of preservation and protection of the environment. Considering all the regulations and directions, Article 8 of the General Environmental Regulations and Its Rules for Implementation outlines that public agencies and persons should use natural resources rationally in the preservation and development of renewable resources and prolonging the duration of use of non-renewable resources.²⁴⁰ It also stipulates that the public agencies and the community should work together to achieve harmony between consumption rates and patterns and the carrying capacity of the available resources. Additionally, recycling and re-use technologies, as well as conventional technologies, which are compatible with the local and regional environmental conditions, should form an integral plan of the environment conservation strategy.

PME should cooperate and coordinate with the concerned agencies in the development of the environmental disaster plan based on the identified available local, regional, and international capabilities.²⁴¹ Concerned agencies should also be committed to the preparation and development of contingency plans needed for the protection of the environment from pollution hazards that may arise from different emergencies that may arise during project implementation. Supervisors of the projects or facilities whose operations could potentially lead to a negative impact on the environment should develop contingency plans, which can be essential in the prevention and mitigation of risks of the project impacts and also the acquisition of means to implement such

²³⁹*General Environmental Regulations And Rules for Implementation, 15*

²⁴⁰*General Environmental Regulations And Rules for Implementation, 17*

²⁴¹*General Environmental Regulations And Rules for Implementation, 25*

plans. The PME also coordinates with the concerned agencies in periodic reviews of the appropriateness of the contingency plans.²⁴² Elsewhere, people who are responsible for the design and operation of the project must conform to the regulations and standards in force. People involved in the operationalization of projects that may lead to some negative impact on the environment must take all the appropriate measures to minimize the potential occurrences.²⁴³

4.7 Powers of Waste Management Authorities

Solid waste management legislation is a major impediment to sustainable waste management in major cities and municipalities. As highlighted earlier, Saudi Arabia lacks comprehensive national and local legislation governing solid waste management issues. In Saudi Arabia, environmental protection policies, including waste management, are handled by the General Authority of Meteorology and Environmental Protection, or PME.²⁴⁴ PME was created in 2001 largely to provide general guidelines on environmental issues to all public and private institutions in Saudi Arabia. However, PME has been more focused on the general environment; thus, waste management has been left to municipal authorities.²⁴⁵ These municipal authorities have enacted disposal standards governing permissibility, method and location of waste disposal sites.²⁴⁶ These standards are intended to protect human health and comfort and promote environmental values.

Saudi Authority for Industrial Cities and Technology Zones (MODON) oversees waste management activities and plans in industrial cities such as Jeddah. MODON is a government

²⁴²*General Environmental Regulations And Rules for Implementation, 26*

²⁴³*General Environmental Regulations And Rules for Implementation, 27*

²⁴⁴*General Environmental Regulations And Rules for Implementation, 4*

²⁴⁵*General Environmental Regulations And Rules for Implementation, 27*

²⁴⁶Mansour, M. A., S. D. Khadir, and I. I. Falqi, 3790

organization that was created in 2001 by the KSA government under the Ministerial Legislation No. 235 dated 27/8/1422H.²⁴⁷ The primary objective of MODON is to regulate and promote industrial estates and technology zones in Saudi Arabia as well as encourage the private sector to participate in the development, operation, and maintenance of the Industrial Estates. MODON currently runs 35 industrial cities and five oases and oversees the spread of these industrial cities over various regions of the kingdom.²⁴⁸ Since 2001, MODON has developed an area of 190 million square meters in industrial cities, such as Riyadh, Jeddah, Dammam, Makkah, Qassim, Al-Ahsa, among others.

Regarding waste management, MODON provides non-hazardous waste collection services from factories through its own contractor and the cost for this service is included in the lease agreement. The waste collected by MODON contractor is disposed of as municipal solid waste in municipal landfills.²⁴⁹ The authority derives its powers from the environmental laws and regulations set by the PME and these laws and regulations are implemented through penalties, regular inspections and leases.

Additionally, the General Authority of Meteorology and Environmental Protection licenses companies to collect and treat hazardous solid industrial wastes. Currently, some of the licensed companies include GEMS, EDCO, SEPCO, Awtad, and Environmental Horizons.²⁵⁰ The municipal authority is also tasked with authorization of specific places and systems for trash collection, deposition, and abandonment of trash elsewhere that can be subjected to civil or

²⁴⁷Modon official websiteArchived 2010-01-24 at the Wayback Machine

²⁴⁸Modon official websiteArchived 2010-01-24 at the Wayback Machine

²⁴⁹Modon official websiteArchived 2010-01-24 at the Wayback Machine

²⁵⁰Faisal K. Alturki, Promoting Sustainable Development Through Environmental Law: Prospects for Saudi Arabia (June 2015)

criminal penalties. Solid waste management standards also may require other wastes to be separated for recycling rather than disposal. Municipal authorities are expected to implement various environmental requirements as provided under the General Environmental Regulations and Its Rules for Implementation.²⁵¹ For example, municipal authorities should coordinate with the PME and other relevant authorities to ensure that anyone, person or organization, performing digging, demolition, construction, debris or dirt transportation should take necessary precautions to attain safe storage and transportation of such materials. The materials must be treated and disposed of following the regulations and the municipal authority codes.²⁵² In addition, smoke, gases, liquid and solid residue from burning fuel, industrial and power generation activities should be within allowable limits as permitted by various environmental standards dealing with waste management.

In Saudi Arabia, it is the responsibility of the Presidency to ensure compliance with waste management standards. For example, PME enacts laws that help the local authorities to handle the waste problem effectively. Though insufficient, the local authorities also receive funding from the PME geared towards effective waste management systems.²⁵³ Besides, the national economic blueprint, Vision 2030, has placed environmental conservation and sustainability at the core of its future economic policies.²⁵⁴ Furthermore, application for a license to open a waste facility must pass through a Competent Agency and the application must also provide proof that the presidency has evaluated the existing facility and plans for the new facility. To improve enforcement of waste management legislation, the Kingdom should consider

²⁵¹*General Environmental Regulations And Rules for Implementation, 29*

²⁵²*General Environmental Regulations And Rules for Implementation, 57*

²⁵³Ouda, Omar K., and Huseyin M. Cekirge, 269

²⁵⁴*General Environmental Regulations And Rules for Implementation, 79*

delegating waste management enforcement powers to the local authorities as this will enhance the speed of clearances and enhance efficiency.²⁵⁵

4.8 Current Laws and Regulation Proposals on Solid Waste Management in Saudi

Arabia

General Authority of Meteorology and Environmental Protection or PME is responsible for the development and implementation of all laws, policies, and regulations about solid waste management and environmental protection in general.²⁵⁶ In the development of waste management initiatives, PME studies the current situation of industrial and hazardous wastes and develop centers for industrial and hazardous waste management and build expertise to operate the center. PME is also responsible for coming up with procedures for addressing industrial and hazardous wastes and working on the waste guidelines. PME applies provisions of various regional and international treaties to manage industrial and hazardous wastes within the country.²⁵⁷ Nevertheless, Saudi Arabia has multiple environmental protection and waste management legislation. For instance, issues touching on waste management were handled by broader national environmental protection standards enacted and implemented by PME.

On the other hand, local authorities manage waste disposal landfills. The role of the people in waste management is to gather their wastes in a waste bag and take them to the collection point.²⁵⁸ Unlike other countries, Saudis are not required to sort their wastes thus making the exercise of waste management even more expensive to the authority.

²⁵⁵*General Environmental Regulations And Rules for Implementation, 99*

²⁵⁶High Commission for the Development of Riyadh, 2

²⁵⁷IBP Inc, 14

²⁵⁸IBP Inc, 16

Modernization of the KSA's existing solid waste management system based on the waste hierarchy will be vital in making waste collection and treatment more effective in the kingdom. To do so, the country must adopt a comprehensive but flexible waste management legislation targeting various waste management issues from funding to the enforcement of standards. Furthermore, the new legislation should also lead to the delegation of implementation duties to the municipal authorities. In addition, municipal authorities should be allowed to work with other stakeholders in realizing the aim of waste management sustainability in the country. In this regard, waste management should be flexible to adopt technology-based, scientific waste management policies to achieve sustainability goals. For instance, anaerobic waste treatment is one of the new waste treatment methods commonly used around the world. Though still a new concept in Saudi Arabia, if fully adopted, it can lead to enhance the effectiveness of the waste management system. The anaerobic waste treatment process encompasses the treatment of waste and sewage using anaerobic digestion.²⁵⁹ During anaerobic digestion, organic matter wastes and wastewaters are transformed into biogas, methane and CO₂ and a rich sludge that can be used as fertilizer. Biogas can be used as a renewable energy source while the sludge can be used in agriculture.

Recent studies have shown that waste can also be treated using new electronic waste treatment methods.²⁶⁰ When electronic wastes are improperly disposed of, toxins can be released to the environment from the disposal processes, such as burning and burring.²⁶¹ To effectively dispose of electronic wastes, components are dissociated and melted to make other products and minimize the negative pollution effects. The remaining parts are then disposed into landfills.

²⁵⁹Joebenson, Francis L., et al, 39

²⁶⁰Taher, Nahed, and Bandar Hajjar. *Energy and Environment in Saudi Arabia: Concerns & Opportunities*, 19

²⁶¹Maloney, Kelly O., and David A. Yoxtheimer, 284

Municipalities can also outsource waste management to private companies. The company will have to be licensed by the local authority and must adhere to Saudi Arabia's environmental protection standards as stipulated by PME.²⁶² These licensed firms can, therefore, gather, sort, recycle, and dispose of all the waste materials from a city or urban area. Besides, most of the community projects on waste in Saudi Arabia focus on the three main areas of reuse, recycling and awareness creation. There are several community organizations in major cities, such as Jeddah that encourage residents to reuse their materials, such as plastic bottles.²⁶³ There also organizations that collect recyclable materials, such as plastics, paper and scrap metals, to make new products, which are sold back to the community. Finally, community organizations teach members of the community on the value of environmental conservation.

Another way of enhancing the effectiveness of solid waste management practice in Saudi Arabia is through cooperation among various stakeholders. For instance, members of the public, national government, municipal authorities, and corporations must work together to realize a successful waste management system.²⁶⁴ The public must be taught on the values of responsible waste handling while the national government must not only make waste management policies but also ensure that scientific approaches to waste management in cities are sufficiently funded. The new waste management policy should also prioritize awareness of the public regarding waste management, especially among city residents. Awareness should cover areas, such as responsible waste disposal, waste sorting, and reuse to enhance the effectiveness of the waste management system.²⁶⁵ The communities and small businesses should be involved more in the

²⁶²Zafar, Salman

²⁶³Taher, Nahed, and Bandar Hajjar, 22

²⁶⁴Vincent, P. *Saudi Arabia: An Environmental Overview*, 9

²⁶⁵Vincent, P, 10

development and implementation of efficient and sustainable waste management strategies. For example, energy-efficient waste management approaches, such as composting of biodegradable wastes or producing electricity or cooking gas from landfills, can be implemented within the communities.²⁶⁶ In this regard, solid waste management policies should promote innovation and use of modern technology to treat, recycle and reuse solid wastes.

²⁶⁶Vincent, P, 21

5 CRITICAL SOLID WASTE MANAGEMENT CHALLENGES FACING SAUDI ARABIA CITIES

5.1 Introduction

Today, Saudi Arabia is witnessing increased industrialization activities, a high population, and a high rate of urbanization. These factors have led to an increase in levels of pollution and waste generation. The country is facing a solid waste management challenge, an indication that both local and national governments have a long way to go in matter sustainable waste management. With a population of about 29 million, the KSA generates about 15 million tons of solid waste with every citizen in the country generating about 1.8 kg of solid waste every day²⁶⁷. Urbanization is high in KSA as more than 75% of the country's population lives in urban areas, which requires the government to improve the waste management sector to protect the health of its population through modern techniques of waste management such as recycling or anaerobic digestion. The three largest cities in KSA, Riyadh, Jeddah, and Dammam produce about a half of KSA's total solid waste with over 6 million tons every year, which indicates the problem facing the local governments, including civic bodies. In KSA, waste management involves the collection of solid waste from individual or community garbage bins before the disposal of the waste into landfills and sometimes in dumpsites. The scenario of garbage bins is an indication of a lack of modern ways of waste management as well as a lack of waste disposal

²⁶⁷ Ai, Ning. "Challenges of sustainable urban planning: the case of municipal solid waste management." PhD diss., Georgia Institute of Technology, 2011.

facilities. The country also lacks a payment system for waste disposal or treatment activity, which indicates budget problems facing civic bodies, especially those tasked with cities' sanitation duties. The landfills in the country are almost reaching their full capacities and it is the most famous practice when it comes to waste disposal in KSA. Other practices that could see the situation improve such as recycling, energy recovery, and reuse are at a very early stage. The involvement of both local and national governments is very low. In fact, the informal sectors have led to an increase in recycling and reuse activities, raising it to about 10-15% around the country. The government provides little to no help to the informal sector who helps extract solid wastes such as metals and plastics from municipal waste.²⁶⁸ The food crisis is also evident in KSA, as the population believes in fresh food, discouraging leftovers. A lot of food from hotels, restaurants, and households is ending up in landfills, polluting the environment.²⁶⁹ However, even with so much food waste, composting is rarely practiced in Saudi Arabian cities. Additionally, converting waste to energy is yet to gain relevant attention or interest from the government or private sector. Talking of the private sector, the cooperation between the sector and government is very low, which has left both national and local governments overwhelmed by the municipal solid wastes.²⁷⁰ The laws and regulations guiding solid waste management in the country are unclear, confusing, and complex, which has led to poor coordination between the local and national governments. For example, MOMRA assists city authorities in the

²⁶⁸ Ouda, Omar KM, Mohammad Rehan, Nader Nader, and Abdul-Sattar Nizami. "Environmental and economic benefits of recovered paper: A case study of Saudi Arabia." *Energy Procedia* 142 (2017): 3753-3758.

²⁶⁹ Hakami, Bader A., and E. S. S. A. Seif. "Household solid waste composition and management in Jeddah city, Saudi Arabia: A planning model." *International Research Journal of Environment Sciences* 4, no. 1 (2015): 1-10.

²⁷⁰ Montagu, Caroline. *Civil society in Saudi Arabia: The power and challenges of association*. Chatham House for the Royal Institute of International Affairs, 2015.

management of solid waste. However, the ministries have to operate under overlapping and multiple jurisdictions. It leaves them with less knowledge of their duties, making it hard for them to enforce these laws. Centralized decision-making is also affecting the waste sector as the national government makes all the relevant decisions even without public or local government involvement.

5.2 Regulatory barriers on waste management in Saudi Arabia

The Presidency of Meteorology and Environment (PME) an agency under the Ministry of Defense, supervises all environmental affairs across Saudi Arabia. The Ministry of Municipal and Rural Affairs (MOMRA) helps PEMA in the supervision of environmental-related activities in the cities but the civic agencies' responsibilities and jurisdictions are unclear. For example, there are no sufficient policies and regulations to help MOMRA carry out its duties in waste management smoothly. The agencies have to deal with the lack of technical and financial capacity to confront high rates of waste generation. For waste management regulations to attain their objectives, regulation, and management of policies need to be effective and efficient. However, regulations in Saudi Arabia are ineffective because there is no institution collaboration, which means enforcement of regulations up to local levels is a challenge in KSA. For example, there is an inadequate collaboration between the governmental, academic, and private sectors. For a waste regulation to work in KSA, all stakeholders must take part in ensuring that it reaches all the intended audiences. However, the monopoly of the national government has created a gap between the planning of waste management regulations and their

enforcement.²⁷¹ Schools are essential in any waste management policy because they help spread its advantages as well as engage in research that is essential in the improvement of waste management practices. The private sector such as banks is essential in the implementation of a regulation. Enforcement or implementation of any regulation requires funding and financial institutions play a crucial part. However, in KSA, there is inadequate private sector involvement in solid waste management, which has left local authorities confronting inadequate funding and poor enforcement of regulations. The national government has all the powers, leaving the local authorities with unclear responsibilities, which increases the complexity in the waste management sector.²⁷²

Another regulatory barrier in Saudi Arabia is the presence of immature strategic policies for solid for effective waste management such as recycling. For cities to attain zero waste, regulations and policies have to be valid. However, in many cases, the national government rushes to enforce immature regulations on local authorities.²⁷³ . In other terms, the national government needs to involve other stakeholders such as the public and local authorities when formulating waste management regulations to avoid immature policies.²⁷⁴ Further, for regulations to work, coordination among all parties has to be high. However, in Saudi Arabia, there is limited coordination between solid waste regulators and generators. There is confusion in households on matters related to solid waste management because government rarely involves them when

²⁷¹ Lippitt, Paul, Andrew Dunwoody, and Andrea Charlson. "Planning for waste minimisation and resource efficiency in HS2." In *Proceedings of the Institution of Civil Engineers-Waste and Resource Management*, vol. 172, no. 3, pp. 65-75.

²⁷² Al-Hasawi, Hamad. "Investigation of municipal solid waste management in GCC states." (1999).

²⁷³ Gharaibeh, Emhaidy S., N. M. Haimour, and Bilal A. Akash. "Evaluation of current municipal solid waste practice and management for Al-Ahsa, Saudi Arabia." *Int. J. of Sustainable Water and Environmental System* 2, no. 2 (2011): 103-110

²⁷⁴ Ejaz, N., N. Akhtar, H. Hashmi, and U. Ali Naeem. "Environmental impacts of improper solid waste management in developing countries: A case study of Rawalpindi city." *The sustainable world* 142 (2010): 379-387

formulating waste regulations. Households are the leading generators of municipal solid waste but national or local authorities rarely involve them when formulating regulatory policies, which creates complexity in municipal solid waste regulation.²⁷⁵ The regulations leave residents without clarity on their responsibilities towards environmental conservation.

Limited authority of the local governments make it hard for them to regulate waste collection and disposal because they find it hard to secure financial, legal, and organizational resources necessary for the implementation of a given regulation or policy on waste management. The national and local authorities result to blame games, which leads to poor implementation of policies, which is an indication of the current Saudi regulation structure. .²⁷⁶ The complexity makes these institutions inefficient and on most occasions dysfunctional. The dysfunctional and inefficient institution makes it costly and impossible to enforce regulations on recycling or modernization of landfills or ensuring sorting at the household level.²⁷⁷ Waste management regulations are left in the hands of people with unfamiliar and disinterested in the needs of the regions, leading to inadequate enforcement of waste disposal or collection laws. The structure of governance in Saudi Arabia leads to duplication of duties and responsibilities, which hinders the implementation of national and regional laws. The national agencies have all the power and resources, leaving the local authorities without tools and funding to deliver or implement waste management regulations. Therefore, the barriers in waste management regulation arise from overlapping responsibilities among local and national authorities. The complexity leads to bypassing and competition between institutions tasked with a similar duty of improving the lives

²⁷⁵ Hakami, Bader A., and E. S. S. A. Seif. "Household solid waste composition and management in Jeddah city, Saudi Arabia: A planning model." *International Research Journal of Environment Sciences* 4, no. 1 (2015): 1-10

²⁷⁶ Gharaibeh, Emhaidy et al., "Evaluation of current municipal solid waste practice and management, 103-110

²⁷⁷ Hakami and Seif, Household solid waste management in Jeddah city, Saudi Arabia, 1-10.

of all Saudi citizens. However, instead of working together, they compete to implement laws and policies, leading to failures in the waste management sector. The obstruction, competition, and bypassing in local and central government waste management is damaging their reputation, making it hard for the public to trust their plans on urban development. In other terms, without a clear definition of responsibilities, Saudi Arabia will find it hard to regulate waste management practices or carry out essential reforms to save cities such as Jeddah from the solid waste menace.

5.3 Other barriers and Impediments to the effective solid waste management in Saudi Arabia cities

It is clear that the Kingdom of Saudi Arabia produces about 15 million tons of municipal solid waste every year. This means that every day, an individual disposes about one kilogram of solid waste. However, it is sad to note that either most of the municipal solid waste collected from individual or community container ends up in landfills and dumpsites untreated. The lack of effective solid waste management is due to the recycling barrier²⁷⁸. Recycling and reuse is at an early stage, which is leading to ineffective solid waste management. During waste recycling and sorting, the informal sector does most of the work, but the main stakeholders recognize the sector, which demotivates them into engaging in more active solid waste management. The recognized or formal stakeholders such as the local authority do not have a ground knowledge about the solid wastes, which leads to inadequate policies²⁷⁹. Therefore, the lack of recognizing

²⁷⁸ de Lorena Diniz Chaves, Gisele, Jorge Luiz dos Santos Jr, and Sandra Mara Santana Rocha. "The challenges for solid waste management in accordance with Agenda 21: a Brazilian case review." *Waste Management & Research* 32, no. 9_suppl (2014): 19-31.

²⁷⁹ Hakami, Bader A., and El-Sayed Sedek Abu Seif. "Household solid waste composition and management in Jeddah City, Saudi Arabia: a planning model." *Int. Res. J. Environ. Sci* 4, no. 1 (2015): 1-10.

the informal sector or involving them in solid waste management is a barrier to effective waste disposal. There is also low awareness about separation of waste in Saudi Arabia. The government has not engaged in campaigns to encourage waste separation at household level. Therefore, household members dispose both organic and solid waste together, preventing thorough solid waste collection from the environment.²⁸⁰ There are cases that municipal leaders are unaware of waste separation. Lack of knowledge about waste separation programs is also preventing effective waste management because the leaders have no knowledge of how to tackle solid waste. There is also inadequate recycling and separation machinery, forcing workers to engage in manual labor.

According to statistics, some solid waste is exceeding over 6 million tons per year, especially in three largest cities in Saudi Arabia Riyadh, Jeddah, and Dammam. This indicates that there is a challenge when it comes to the collection of solid wastes.²⁸¹ As above stated, recycling, and waste management is supported by weak government policies, which are slow in adoption of new waste management technologies. The solid wastes in all cities are collected from community or an individual bin, after which they dispose the solid waste in dumpsites or landfills. Some of the landfills and dumpsites are full which makes solid waste scatter all over. However, the level of solid waste is accumulating rapidly in Saudi Arabia because recycling, reuse, and conversion of the waste to energy has not started in some areas, and where it has, and it is at its early stage. The government has not, for many, years paid attention regarding recycling

²⁸⁰ *Waste Management & Research* 32, no. 9_suppl (2014): 19-31.

²⁸¹ de Lorena Diniz Chaves, Gisele, Jorge Luiz dos Santos Jr, and Sandra Mara Santana Rocha. "The challenges for solid waste management in accordance with Agenda 21: a Brazilian case review." *Waste Management & Research* 32, no. 9_suppl (2014): 19-31.

and energy reuse methods. The rates of recycling are about 10% but only because there is active informal sector. The formal sectors who are biggest contributors of solid waste do not engage in collection or separation of waste products. The few youths engage in the extraction of papers, metal, and plastics, separating them from the organic waste. However, they cannot separate all the solid wastes, which make much of the solid waste to end in the landfill or dumpsites.

It is clear that Saudi Arabian cities are facing a solid waste menace. The communities require more help than just use of informal sector to collect the solid waste. Additionally, the central and local government provides less help than they should be providing leaving the informal sector to struggle with resources. There is also the problem of financial problems by the municipals whereby the money allocated to the local governments of Saudi Arabia is inadequate to cover the issue of waste collection, let alone separation and recycling of the solid waste. Further, the limited resources by the municipalities have made it difficult for them to buy equipment and infrastructure that can cater for the collection of waste that is increasing at an alarming late. Therefore, the informal sector is trying to reduce solid wastes within the municipalities, but the inadequate infrastructure and equipment such as waste dumping bin. The waste collected from individuals or community bins requires transportation to the dumpsite or landfill, however, the municipals have less transfer and transport equipment. The lack of transportation means allow some areas to go days without waste collection service, thus leading to accumulation of solid wastes in Riyadh, Jeddah, among other developing Saudi Arabian cities.²⁸² The lack of infrastructure and resources as above mentioned, is a barrier to solid waste management because it makes residents result to improper waste disposal and collection

²⁸² Alhumoud, Jasem M. "Municipal solid waste recycling in the Gulf Co-operation Council states." *Resources, Conservation and Recycling* 45, no. 2 (2005): 142-158.

methods. The residents of the highly industrializing nation have resulted to dumping solid wastes into the environment because waste collection services cannot reach them due to waste transportation and transfer problems. Alternatively, people are using the burning methods due to municipals inefficiency as well as lack of infrastructure. However, although one can completely burn organic wastes, it is difficult to burn solids such as metals. Therefore, domestic burning as a solution to solid waste disposal is doing a very little help because most of the incompletely burnt solids end up in the city environs. Additionally, many projects regarding solid waste collection are failing as illustrated by Shekdar (2009).²⁸³ The failure of these projects has been contributed by inadequate monitoring by the local governments. Therefore, one can state that one barrier to effective solid waste management is collapse of collection facilities and failure to collect mean that solid waste will continue accumulating in the developing cities. Another impediment is government incompetency. Poor working by the municipal agents and inadequate monitoring is preventing effective collection of solid wastes.²⁸⁴ They also do not check the equipment and the set infrastructure to determine its compatibility with the features of solid wastes. This is an illustration that local authorities have limited knowledge about management of solid wastes. Furthermore, the final disposal process is an impediment to solid waste management. Many available dumpsites are open and have no leachate treatment or protection at the bottom. There are some people or those tasked with disposing the solid waste, instead of dumping the waste into the official disposal sites, dump it anywhere or at an illegal place such as rivers, lakes, and oceans, and on the roadsides. Failure to have a common dumping place leaves solid waste to be

²⁸³ Alhumoud, Jasem M. "Municipal solid waste recycling in the Gulf Co-operation Council states." *Resources, Conservation and Recycling* 45, no. 2 (2005): 142-158.

²⁸⁴ *Resources, Conservation and Recycling* 45, no. 2 (2005): 142-158.

dumped all over the towns, thus becoming an impediment to its treatment, which means that solid waste continues to accumulate. The analysis illustrates that municipalities within Saudi Arabia are doing inadequate work in supporting solid waste management. They offer inadequate infrastructure, which can be due to less funding from the central government. Additionally, some of the officials have less or no knowledge about effective solid waste disposal methods, which make them purchase facilities incompatible with solid waste management. Therefore, incompetency of municipals and inadequate monitoring of solid waste collection activities has been a big impediment to effective solid waste management in Saudi Arabia.

5.3.1 Lack of adequate dumping bins

One city in Saudi Arabia struggling with a rise in solid waste is Jeddah. Its population is increasing at an alarming rate where its population at by the year 2018 was around 3.5 million. The high population produces about 5,000 tons of solid waste every day to a point that Jeddah municipality is finding it hard to cope with the menace of the urban waste.²⁸⁵ Collection of wastes in these cities, including Jeddah, is done by emptying wastes from bins that are placed across many residential and commercial areas. However, not all areas have the bins, which force them to dump waste at illegal places. According to the municipals, the money required to place dumping bins all over residential and commercial areas is a lot, which means that the municipals have just placed the bins in few designated areas. The inadequacy of dumping bins forces residents to throw wastes into the rivers and already full landfills. Additionally, there are very few recycle bins in the cities. The collected waste instead of being thrown into recycling bins end up in lakes, as the transfer facilities have no other places to dump the wastes. The evidence of

²⁸⁵ Khan, Muhammad Sadiq Munfath, and Zakariya Kaneesamkandi. "Biodegradable waste to biogas: renewable energy option for the Kingdom of Saudi Arabia." *Int. J. Innov. Appl. Stud* 4, no. 1 (2013): 101-113.

solid wastes in rivers and lakes is evident by their rising water tables due to increased dumping of industrial wastes into the water bodies, which means that residents have inadequate dumping bins. The lack of provision of dumping bins by the municipals has made many institutions to provide and maintain their own dumping and recycling bins. For example, Effat University provides recycling bins where one puts waste after being color-coded in different bags.

Saudi Arabia is experiencing rapid industrialization, which is leading to increased population. However, the municipals are slow in monitoring the rate of population growth and that of waste increase.²⁸⁶ They continue utilizing same amount of dumping bins and recycling bins without realizing that the population has increased. Therefore, the population is left to share the little available dumping bins, meaning that the available bins are inadequate to the rapidly increasing population. Reports indicate that Saudi Arabia losses around SR 40 billion due to inadequate dumping bins as stated by Deputy Executive Director of Saudi Environment Society. The inadequate bins means that sorting of wastes will be inadequate, especially in Jeddah. The common waste bins are yet to be supplied to all homes, which mean that residents cannot fully engage in sorting and proper waste disposal.²⁸⁷ The residents are forced to engage in unfriendly practices and cannot engage in waste sorting at their homes. The shortage of dumping bins has led to the establishment of centers made of fiberglass to prevent bacteria and insects, but they are only available within few places across cities.

²⁸⁶ Khan, Muhammad Sadiq Munfath, and Zakariya Kaneesamkandi. "Biodegradable waste to biogas: renewable energy option for the Kingdom of Saudi Arabia." *Int. J. Innov. Appl. Stud* 4, no. 1 (2013): 101-113.

²⁸⁷ Anjum, Muzammil, Muhammad Waqas, Ijaz Ahmad, and Mohamed Barakat. "Solid waste management in Saudi Arabia: A." *Journal of applied Agriculture and Biotechnology* 1, no. 1 (2016): 13-26.

The proper way of collecting waste is to have two waste dumping bins where one belongs for recyclables while other for non-recyclables. The practice need to start from the kitchen, office, and other areas of consumption. However, this is not the case in Saudi Arabian cities as even a single bin is in some places unavailable. The inadequacy of such bins is forcing residents to combine both recyclable and non-recyclable wastes in a single dumping bin, which is later emptied by the municipal transfer and transport facilities to the dumping sites. The lack of two waste bins for the households and community is a sign that Saudi Arabia experiences shortage in dumping bins. To curb the problem charity organization have engaged in the practice of providing residents with two waste bins and educating them how to sort it properly. The organizations make an effort of buying the waste collected by an organization like Hyperpanda stores. According to the organizations, their effort is to try helping Saudi Arabia shift to single stream recycling.²⁸⁸

Single stream recycling means that all recyclables are placed in one dumping bin. However, in Saudi Arabia, this is not the case as bins provided are inadequate. Residents are provided with single common dumping bin, which does not allow single streaming. This forces urban residents in Saudi Arabian cities to combine organic and solid wastes together, thus making it difficult to manage the available solid wastes at the landfills and in the dumpsites. Instead of separating the wastes at the homes or offices, the informal sector, tasked with municipal waste collection do the sorting after emptying the household and community dumping bins, which also illustrate that residents combine their food wastes and solid wastes.²⁸⁹ The

²⁸⁸ Anjum, Muzammil, Muhammad Waqas, Ijaz Ahmad, and Mohamed Barakat. "Solid waste management in Saudi Arabia: A." *Journal of applied Agriculture and Biotechnology* 1, no. 1 (2016): 13-26.

²⁸⁹ *Journal of applied Agriculture and Biotechnology* 1, no. 1 (2016): 13-26.

combination is an evidence that the dumping bins provided to the urban residents are inadequate for they do not promote separation of wastes. Even with the knowledge of waste separation by Saudi Arabians, the lack of enough dumping bins mean that people will not separate recyclables and non-recyclables, which indicates that solid waste accumulation will continue in the future because few dumping bins will force the city dwellers to continue throwing all their waste in a single dumping bin. The shortage has even made recycling factories, especially in Jeddah to provide dumping bins that promote waste separation. To compensate the shortage of bins in Jeddah, for example, Trewind Recycling Plant has helped the municipals by adding collection bins at public places such as schools, hotels, offices, and hospitals.²⁹⁰ However, if the government of Saudi Arabia had provided all the residents with adequate dumping bins, there would be no need to involve private entities into adding these facilities to the public institutions. Additionally, if government funded institutions lack dumping bins, this means that the situation is worse in many private entities.

5.3.2 The irregularity of the waste collection

Urban waste management has become a big challenge for the Saud Arabia government due to the irregularity of waste collection. The nation is experiencing rapid industrialization, which means that waste accumulation rate is on the rise, but the rate of waste collection is very slow, thus leading to the accumulation.²⁹¹ Additionally, there is no formal sector established by

²⁹⁰ Gharaibeh, Emhaidy S., N. M. Haimour, and Bilal A. Akash. "Evaluation of current municipal solid waste practice and management for Al-Ahsa, Saudi Arabia." *Int. J. of Sustainable Water and Environmental System* 2, no. 2 (2011): 103-110.

²⁹¹ Abosuliman, Shougi Suliman, Arun Kumar, Firoz Alam, and R. Rasjidin. "Disaster planning and management in Jeddah, Saudi Arabia." In *Proc. 2013 International Conference on Economics and Social Science (ICESS 2013)*, pp. 20-21. 2013.

the government to deal with the collection. Instead, the task is left with municipal officials who have inadequate knowledge about waste management. Irregularity starts at the residential level whereby many urban residents have no means of separating their wastes. The shortage of dumping bins forces people to engage in irregular waste disposal, making it difficult to separate the recyclables and non-recyclables. Additionally, the informal sector engages in both collection and sorting of the wastes. This illustrates irregular waste collection as government should have insisted on separation of wastes to allow the informal sector to only engage in collection of already sorted waste. Therefore, the method of emptying one common bin and then proceeding to sort is irregular because it is time consuming and costly because the informal sector performs duties of householders.²⁹² It also increases the transport and transfer costs because the waste is first transported to dumpsites and landfills for sorting. The recyclable materials are then transferred to recycling plants, which is a double transportation cost. However, if sorting happens at the homes and offices, trucks would only engage in transporting the recyclable wastes direct to the factory without having to pass through any dumpsite or landfill.

When waste is collected from offices or households, the best way is to recycle or treat the waste. However, in Saudi Arabia, this is not the case because waste collectors engage in irregular waste disposal. They load the waste in their trucks and proceed dumping it at the dumpsites and landfills without processing it or treating it. This is irregular because the solid waste will negatively affect the environment because some solids may fail to decompose. Further, the decomposing waste may lead to air pollution as they dump it in open dumpsites, which puts those near the sites at risk of breathing complications. Additionally, even though the informal

²⁹² Elhadj, Elie. "Household water and sanitation services in Saudi Arabia: an analysis of economic, political and ecological issues." *Occasional paper* 56 (2004).

sector tries sorting the wastes, they contribute to just 10 percent which means 90 percent of waste is disposed without sorting or treatment, a clear show that waste collection in Saudi Arabia is irregularly done.²⁹³ Additionally, much of the waste management processes involve government funding leaving the private sector out. However, most of wastes in the lakes and oceans are from private industries, which means that they too need to account for their waste disposal but this is not the case. Although, there are ways government is involving the private sector in waste management, it is still inadequate as many private sectors engaging in waste treatment are charitable organizations. Further, instead of the industrial enterprises receiving high fines for pollution, they receive few low fines, which are not deterrent to their illegal activities. Irregularity is evident when one compares the level of damage wastes causes to the economy and the fines imposed. They are very unequal as deaths of aquatic animals due to sewage waters direction into lakes cannot be comparable to the amount being asked as fines. One can state that there is corruption in terms of waste management because instead of imposing high fines on factories to help in finding resources to effectively handle waste, the company owners collude with courts, and they end up escaping justice. As indicated above, sewage water from many Saudi Arabian cities is directed to water bodies, which end up killing the aquatic creatures. The government does one good thing of eliminating the sewage water but end up causing more losses after dumping the waste into the water bodies.

It is interestingly to note how industries in Saudi Arabia are on the rise. The rapid industrialization experienced in the nation result from high use of modern technologies, which

²⁹³ Elhadj, Elie. "Household water and sanitation services in Saudi Arabia: an analysis of economic, political and ecological issues." *Occasional paper* 56 (2004).

increases the rate of production, thus expanding the Saudi Arabian economy.²⁹⁴ However, the same is absent when it comes to waste management. Instead of government adopting waste management technologies it has in industries, the country continues to struggle with traditional methods of waste production. If the traditional methods are the one being applied in industries, the country would not be in its current economic position. The country is earning a lot of foreign exchange given that it is one the largest oil producing country. However, the revenues come at the expense of environment as oil drilling and refining lead to increased solid waste accumulation. Instead of preserving the environment that brings revenue to the government, the revenue goes to bill settlements, leaving wastes to continue accumulating. The application of technology in waste management is very irregular with many reports indicating that the conversion of waste into energy or recycling them for reuse is at an early stage. The technology applied is very irregular and unsustainable. Instead of installing recycling bins, the municipals are busy filling the dumpsites with untreated waste. These landfills are prone to greenhouse gas emissions and flies, which are hazardous to the environment. The government lacks an integrated waste management strategy because of its reluctance to apply modern technologies to tackle the heaps of garbage accumulating across all Saudi Arabia major cities. Irregularity in tackling waste by the Saudi government is clear with the continued opposition by the Kingdom of Saudi Arabia government of international laws, mainly on climate change. Although the government is showing its commitment in fighting the waste accumulation menace through budget increases, its practices contradict government stand in line with the international policies. For example, instead of the Saudi government supporting reduced global carbon remittance, the government fought

²⁹⁴ Gause, Gregory F., F. Gregory Gause III, and F. Gregory Gause. *Oil monarchies: domestic and security challenges in the Arab Gulf States*. Council on Foreign Relations, 1994.

the international policy in a bid to safeguard their industries. The government values economic progress more than environmental conservation, which illustrates an irregular commitment by the government to fight climate change by reducing environmental pollutions. Further, local authorities are receiving inadequate resources while others have inadequate knowledge, making the finances aimed at waste management to be utilized inefficiently.²⁹⁵ For example, some municipal officials engage in less monitoring activities of waste collection or compatibility of facilities with waste collection. This makes many facilities and projects to fail, leading to losses of taxpayers' money for the local government engages in non-viable practices. Therefore, the lack of sustainable funding of municipalities, lack of waste sorting at the household level, lack of treatment and low levels of recycling illustrates irregularities in collection of wastes. This has made many to lose hope in government projects making many to refuse paying for any service regarding any improvement of current methods of waste collection in Saudi Arabia. Such irregularities have seen some parts to have more waste accumulation than the other has. For example, more plastic-pellets are observable at the east coast on the Gulf of Oman compared to those present at the west coast on the Arabian Gulf. The irregularities also make the Arabian Gulf to be more polluted with industrial plastic than other parts of the world.

5.3.3 Social-cultural and religious barriers

In Saudi Arabia, majority of the inhabitants are Muslims who generate a significant amount of waste during social and religious occasions, especially during the fasting month

²⁹⁵ Gause, Gregory F., F. Gregory Gause III, and F. Gregory Gause. *Oil monarchies: domestic and security challenges in the Arab Gulf States*. Council on Foreign Relations, 1994.

Ramadan.²⁹⁶ According to statistics, majority of the food, thirty to fifty percent, during the holy month end up in landfills. These social and religious occasions have become a headache in waste management sector because there are no proper disposal methods in place. Most of the food end up in open dumpsites, produces harmful greenhouse gases which is a great cause of climate change worldwide. In Saudi Arabia, the present landfills and dumpsites are expected to reach maximum capacity within the next ten years, but the rapid increase in population and waste accumulation rate, food wastes from religious and social gatherings is threatening to shorten that time. Food waste comprises of organic waste, mainly generated by the household sector. Commercial sectors dealing with food and drink factories also contribute to the increase in food wastes across Saudi Arabia. Apart from the food wastes, the packaging materials are also adding up to the wastes.²⁹⁷ People during Ramadan or other religious holidays wrap their food using unsoiled papers or newspapers. Other food wastes include inedible and non-avoidable food items such as the eggshells and tea bags. However, the most dangerous issue about food waste from social and cultural occasion cannot be treated or recycled. People do not understand that the leftovers they throw away while on celebrations contains high sodium and salt levels, including moisture, all which end up being mixed in the dumping bins. Social practices such as household chores are unavoidable, especially in a country like Saudi Arabia with millions of population. Other social barriers to waste management include religious occasions like Ramadan and street food vending. Research indicate that the current generations are wasteful than the older

²⁹⁶ Baig, Mirza B., Khodran H. Al-Zahrani, Felicitas Schneider, Gary S. Straquadine, and Marie Mourad. "Food waste posing a serious threat to sustainability in the Kingdom of Saudi Arabia—A systematic review." *Saudi Journal of Biological Sciences* (2018).

²⁹⁷ Gharaibeh, Emhaidy S., N. M. Haimour, and Bilal A. Akash. "Evaluation of current municipal solid waste practice and management for Al-Ahsa, Saudi Arabia." *Int. J. of Sustainable Water and Environmental System* 2, no. 2 (2011): 103-110.

generations, which means that social and cultural practices need thorough evaluation in reaching a solution to challenges facing waste management in Saudi Arabia. The government should not only focus on industrial wastes and solid wastes, because as reports indicate food waste is a headache to waste management and the rise in wastages especially in the holy month of Ramadan is threatening the available landfills and dumpsites. Therefore, food as a cultural issue needs evaluation because roadside shops are on the rise and they use unsoiled packing materials, which end up, scattered across the cities, adding to the already polluted environment.

It is, therefore, correct for the study to state that the increasing waste from left over foods is due to materially organized cultural and religious occasions. As earlier illustrated, poor operational management, inappropriate laws and regulations, poor planning, and outdated technology has made many waste treatment plants in Saudi Arabia to remain closed.²⁹⁸ The local companies, who are also the producers of food supplied to social events, control the food waste plants. However, even after winning contracts repeatedly, they continue to do shoddy work. Additionally, there are no enforcement to waste treatment before disposal, which has added to the waste treatment plant's laxity. It is true that religious, social, and cultural occasions and gatherings are healthy for society progress. Further, food is essential for it provides people with the required energy for their survival but the eating habits of people living in Saudi Arabia is threatening the environment. Landfills and dumpsites are almost full due to tons of food coming from Eid festivals, weddings, and parties. Data shows that food comprises the largest percentage of waste in Saudi Arabia. The main reason is that food is tied to the Saudi Arabian culture, meaning that the waste is inevitable. The study acknowledges that it is a tough challenge for

²⁹⁸ Baig, Mirza B., Khodran H. Al-Zahrani, Felicitas Schneider, Gary S. Straquadine, and Marie Mourad. "Food waste posing a serious threat to sustainability in the Kingdom of Saudi Arabia—A systematic review." *Saudi Journal of Biological Sciences* (2018).

Muslims in Saudi Arabia not to throw away food in a culture where food is everywhere. However, the wastage is making the environment and the economy to suffer because many seem not to mind leaving food on their plates.²⁹⁹ The wastage of food illustrates poor planning in Saudi Arabian household; a sign that waste management team in Saudi Arabia is up for a huge task. According to the culture in the Kingdom of Saudi Arabia, leftovers are unhealthy and should be thrown into the dumping bin. However, they fail to understand that the left food will become a menace to the society once it is improperly dumped. The culture in Saudi Arabia does not advocate for food wastage reduction, instead the measures and policies are inclined towards recycling (compositing) and disposal of the food wastes into the landfills.

A solution to an increase in waste starts by calculating the amount of waste being produced daily by industries.³⁰⁰ However, it is difficult for the government of Saudi Arabia to determine the amount of food waste because there is no available data of food wasted during religious occasions like the Ramadan or other Muslim festive celebrations. During these social events such as births, weddings, and religious celebrations, food come in large scale with some using the chance to flaunt their wealth. Data shows that for an average wedding in Mecca, Saudi Arabia, food available can feed over 300 hungry people. According to Arab news, the food wasted in Mak kah can feed millions, but still there is no data to show the amount of food wasted during such occasions. However, even with all the evidence, government and Saudi experts are

²⁹⁹ Abiad, Mohamad G., and Lokman I. Meho. "Food loss and food waste research in the Arab world: A systematic review." *Food Security* 10, no. 2 (2018): 311-322.

³⁰⁰ "Food loss and food waste research in the Arab world: A systematic review." *Food Security* 10, no. 2 (2018): 311-322.

unwilling to pursue the issue of food wastage.³⁰¹ Many Arab countries including Saudi Arabia have very few published studies about food wastage or ways to prevent or reduce it. Therefore, in future, agencies tackling the issue of food wastage as they try managing wastes in Saudi Arabia will have a big problem due to data unavailability. The main issue preventing food wastage from being fully addressed because food is a culture in Saudi Arabia. Every occasion be it cultural such as a wedding or religious such as Ramadan, food has to be available in plenty. The tie between food and culture make food a hot topic to discuss its contribution to wastes because it is like attacking the country's culture.

5.3.4 Economic barriers

Saudi Arabia is an industrial country, but its production habits do not promote economic sustainability for lack of observing environmental growth. In other terms, the country is yet to attain a green economy, which means transformation of the whole economy from what is produced to how waste is disposed of.³⁰² The waste sector, touching on environmental position, contributes to the overall economy, which means that economy play crucial role when it comes to waste management. To attain an economic efficiency, in the waste context, it reaches when the amount of waste generated is equally collected. The main economic barrier to attaining optimal waste management in Saudi Arabia is the financial barrier. Financial factors result where the municipality receives less money from the central government, making it difficult to adopt new

³⁰¹ Baig, Mirza B., Khodran H. Al-Zahrani, Felicitas Schneider, Gary S. Straquadine, and Marie Mourad. "Food waste posing a serious threat to sustainability in the Kingdom of Saudi Arabia—A systematic review." *Saudi Journal of Biological Sciences* (2018).

³⁰² Alshuwaikhat, Habib M., and Yusuf A. Aina. "Sustainable planning: the need for strategic environmental assessment-based municipal planning in Saudi Arabia." *Journal of Environmental Assessment Policy and Management* 7, no. 03 (2005): 387-405.

technological methods of waste management. Additionally, there are cases of poor financial planning in Saudi Arabia, leading many recycling firms to close. One major cause to this economic barrier is lack of proper waste management fee collection. The government of Saudi Arabia is tasked with the issue of waste collection with less involvement of the private sector. However, the funding to the municipalities is not enough to control the rising accumulation of wastes. The main challenge is that the local and central governments lack a clear fee system for waste collection services. With a proper payment system, the money collected from households could help in motivating the informal sector. It is also a way of increasing employment for the unemployed. The commercial businesses contribute to the dumping of wastes without having to pay a tariff, which is leading to financial strain among the waste management departments. However, the failure for there not to be a payment system is because people have no confidence in government in terms of waste management. The government has frustrated them for years for not implementing proper disposal methods and until they restore the public faith, economic barriers will continue derailing processes of waste management in Saudi Arabia.³⁰³ Others believe that they can manage their own wastes, which adds to municipal's financial constraints. After collapse of many recycling plants, few fee collectors hardly come, which has made many cities to accumulate wastes due to lack of collection services. The financial barrier is also preventing Saudi Arabia from adopting the green technology, which requires millions of investments, and funding from the government. To fully manage its wastes, Saudi Arabia must shift from traditional methods to modern methods of waste disposal. For example, the country can start by converting its wastes to energy, but these power plants require high funding, a thing

³⁰³ Assaf, Sadi A., and Sadiq Al-Hejji. "Causes of delay in large construction projects." *International journal of project management* 24, no. 4 (2006): 349-357.

government of Saudi Arabia has not managed to accomplish, although continued rises in waste management budget gives one hope. The solid in the cities cannot be recycled or converted into wastes because the governments, mainly local governments have no such resources at their disposal. Adoption of green technology requires prevention of greenhouse gases from reaching the environment, which means that the government has to ensure carbon released in the air is at a minimum level. However, to collect carbon in a factory requires sophisticated equipment, which are costly to install across Saudi Arabia. To manage waste, the government needs to put in place recycling bins all over the cities to ensure that all solid wastes are recycled and non-recyclables treated. Economic hardships force the government to dump wastes into open dumpsites and landfills without treatment. The rotting food wastes present at these open dumpsites end up in the air as green gas, which leads to climate change. The government would like to prevent the greenhouse gases but financial constraints is forcing it to dump untreated wastes, making it difficult to manage pollution or climate change.

The money directed towards waste collection at the municipality level goes to paying trucks, maintenance, fuel, and waste disposal. Therefore, supplying of different bags to households becomes difficult for the municipalities to undertake due to the insufficient funding. In addition, poor planning and management leads to wastage of already inadequate fund. Therefore, it becomes extremely difficult for the local governments to promote waste separation because the money is not even enough to supply all households with dumping bins. The bags require labeling to assist an individual where to throw the organic and the solid waste. Further, waste management requires sensitization about proper methods of waste disposal. Sensitization requires government to engage in educational campaigns across Saudi Arabia and in the media, which requires funding. However, insufficient funds allocated to the local municipalities hinder

them from educating the public. For example, food waste is among the largest contributor of Saudi Arabia's total waste. However, the reason for its accumulation is that food and culture go hand in hand, as earlier illustrated.³⁰⁴ Therefore, a vigorous campaign is advisable across Saudi Arabia especially during holidays to urge people to engage in less food dumping due to its adverse effects on the environment. Although such practice can go a long way in reducing food wastes, the financial constraints hinder the relevant agencies from engaging in such educational campaigns. Another economic barrier to effective waste management is that Saudi Arabian waste has no value. Value from waste arises when there is demand for the discarded materials. However, as studies has illustrated, many of recycling plants that could have bought such discarded materials already closed their operations. The value of a waste starts with waste separation, a practice absent in many cities across Saudi Arabia. The informal sector only benefits from waste sorted from 10 percent of total waste in the nation. Majority of valuable waste materials such as plastics and metals end up in landfills and dumpsites and farmers cannot even use the organic waste to farm or feed their stock. Many waste pickers in Saudi Arabia take the waste direct to the fills, reaping no value from it. However, if the practice is adopted, and country engage in separation, the wastes across the cities of Jeddah and Riyadh will have value that will assist in funding waste management projects. However, the cities and municipalities depend on government funding instead of engaging in innovative projects, leaving them underfunded and dirty, which makes financial barrier a constraint towards establishment of effective waste management system in Saudi Arabia.

³⁰⁴ Karim, M. Azharul, Mubarak Aljuhani, Ray Duplock, and Prasad Yarlagadda. "Implementation of lean manufacturing in Saudi manufacturing organisations: an empirical study." In *Advanced Materials Research*, vol. 339, pp. 250-253. Trans Tech Publications, 2011.

5.3.5 Illegal waste disposal

The large cities in Saudi Arabia such as Jeddah, Madina, and Mecca contribute to half of all waste production in Saudi Arabia.³⁰⁵ However, even though the country continues to develop economically, with industrial wastes on the rise, there are no programs in place to sort, recycle, or dispose waste using safe ways. Due to the waste management system failure, people have resulted to illegal dumping, creating a huge challenge to waste management team in Saudi Arabia. There is the shortage of dumping bins and reserve areas for throwing away waste is not clearly defined³⁰⁶. Due to these problems, companies and individuals construct their own illegal transfer stations. Other people engage in throwing waste along the roads and into the water basins. The illegal dumping of untreated waste is affecting effective waste management in the country. Sewerage companies have also resulted to dumping raw sewage into rivers and ocean, threatening the aquatic lives. The illegal dumping is causing rise in sea levels because of plastic pellets deposited in the ocean by trucks that have no designated areas to throw their waste because disposal facilities are minimal if they exist at all in Saudi Arabia. Furthermore, Saudi Arabia is a big oil producer, which means most solid oil wastes end up being illegally dumped for the government has failed to establish adequate and safe dumping destinations. The shortage or absence of dumping areas forces the tanker crews to clear their wastes at night in water bodies causing significant environmental damage. In many cities across Saudi Arabia, it is common to find illegal wastes dumped everywhere. They dump them on roadsides especially unsoiled and newspapers used to wrap foods during festivities and holy month of Ramadan. It is illegal

³⁰⁵ Vincent, Peter. "Jeddah's environmental problems." *Geographical Review* 93, no. 3 (2003): 394-412.

³⁰⁶ Vrijheid, Martine. "Health effects of residence near hazardous waste landfill sites: a review of epidemiologic literature." *Environmental health perspectives* 108, no. suppl 1 (2000): 101-112.

dumping because the waste causes harm to the environment through emission of greenhouse gases that lead to climate change.³⁰⁷

One can contribute the rise in illegal dumping to high levels of waste production in Saudi Arabia. As the study has illustrated this far, Saudi Arabia is experiencing rapid industrialization whereby population in urban centers are on the rise due to foreigners who flock the cities every day. However, the municipalities are not tracking the rise in population for the old waste services continue to serve the already overpopulated urban centers. The other cause is that truck owners and industries are avoiding disposal fees at the waste management sites. Usually, the trucks are required to take their wastes to a disposal site whereby they are allowed to dispose their waste after paying an agreed fee. In many occasions, many find it difficult to pay the fees because of their frustration with poor government services or for lack of the money. Household residents are also unwilling to pay the disposal fees, which makes them result in disposing the wastes themselves. Many residents feel that waste collection is their right and that the fees are excessive. Therefore, instead of them following the correct disposal guidelines, they end up disposing the waste or paying a third party to dispose it illegally. Arab News illustrates how one driving through Saudi Arabia cities such as Jeddah experiences illegal dumping first hand. There are several piles of rubbish, leftovers of construction projects that have been illegally dumped during the night by workers from dishonest contractors. This supports that illegal dumping result from people avoiding using legal disposal means because even their work, such as a construction

³⁰⁷ Vrijheid, Martine. "Health effects of residence near hazardous waste landfill sites: a review of epidemiologic literature." *Environmental health perspectives* 108, no. suppl 1 (2000): 101-112.

is illegal. However, the reason for the rise in illegal activities and dumping is inadequate management and monitoring by the local authorities.

In 2006, Jeddah had about 10 million cubic meters of illegally disposed construction wastes.³⁰⁸ The Jeddah municipality tasked with waste management in Jeddah faces many challenges from these illegal dumpsites. They have to put in extra costs to move the illegally dumped wastes to the designated landfills. The money diverted to the transfers of illegal wastes prevents the cities from implementing safe methods of waste disposal. The Interior Ministry in Jeddah and other cities is also struggling with illegal dumping sites inside residential districts. The directive came after several health hazards resulting from burning of the accumulated wastes within residential areas. The government aims to remove the illegal dumpsites in residential places because they pose danger to the health and safety of residents. Ministry reports indicate that Saudis and expatriates own illegal dumps where they store scrap materials and other wastes. The residents in the areas complain of foul smells due to greenhouse gases emanating from the decomposing organic wastes. Government statistics that by end year 2015, Hindawiyah District had over 37 illegal dumps and such dumps make it hard to control waste disposal in the cities³⁰⁹. It also makes it difficult for Saudi Arabia to develop a streamlined waste management system. The illegal dumping has threatened the few lakes available in the desert of Saudi Arabia. In east of Jeddah, odor of toxic sewage dump welcomes one to the city. The country has no citywide wastewater system, despite it generating million dollars from oil exportation. People in Jeddah

³⁰⁸ Kabir, Shahid, Abdulmoez A. Al-Ismaeel, Abdulaziz Y. Bu Aeshah, and Fahad S. Al-Sadun. "Sustainable management program for construction waste." In *ACI-9th International Conference and Exhibition: Concrete for Sustainable Construction, Bahrain*. 2013.

³⁰⁹ Kabir, Shahid, Abdulmoez A. Al-Ismaeel, Abdulaziz Y. Bu Aeshah, and Fahad S. Al-Sadun. "Sustainable management program for construction waste."

dump their wastewater into the Musk Lake. The inadequate funding has led to stalling of sewerage systems development making people to continue using lakes as dumpsites³¹⁰. Although the cities are trying to treat the sewage water, the facilities are not enough and this has forced people to wait at the night when security is minimal to dump their wastes illegally in open fields, leaving Saudi Arabia to struggle with health hazards and increased challenges of waste management.

³¹⁰ Baiamonte, V. and Vermeersch, E., 2011. Environmental crime and instability: the role of criminal networks in the trafficking and illegal dumping of hazardous waste. *Freedom from Fear*, 2014(9), pp.30-35.

6 CHALLENGES TO SUSTAINABLE SOLID WASTE MANAGEMENT IN SAUDI ARABIAN CITIES

6.1 Introduction

Many cities in Saudi Arabia, including Jeddah, are facing challenges in solid waste collection and disposal. One major reason is that the volume of municipal solid waste (MSW) is increasing each year mainly due to population growth, global urbanization, and rise in industrialization activities as well as economic development. For example, the city of Jeddah is grappling with a swelling population, change of habits, and reduced awareness of the effect of solid waste on the city's environment. Jeddah is a major commercial center being the second-largest city in Saudi Arabia. The rising population in the city means that solid waste management is and will be a problem if the city does not come up with sustainable legislation and measures. With a population of about 3.5 million, Jeddah city produces over 5,000 tons of solid waste every day. Such high volume has made it difficult for Jeddah municipal authority to cope with the problem of urban waste.³¹¹ The management of solid waste in Jeddah involves the collection of wastes from bins placed across residential and commercial regions. Those responsible for the collection of wastes from these bins then send it to transfer stations before its final destination at dumping sites/landfill. One famous landfill in the city of Jeddah is in Buraiman. The landfill receives about 1.5 million tons of waste every year, with an expected duration of 30 to 40 years. The city of Jeddah encounters many other challenges in waste management systems.³¹² One is

³¹¹ Zafar, Salman. "Waste management in Jeddah." (2013).

³¹² Ai, Ning. "Challenges of sustainable urban planning."

limited areas for a landfill due to increased construction and utilization of open lands. The costs of waste disposal are also high taking into consideration the level of pollution from the poor disposal of solid wastes. The city is trying to create awareness through reduce, reuse, recycle campaign to help reduce the waste amounts.

6.2 Existing waste management legislations and practices in Jeddah

To ensure smooth and sustainable waste management, KSA and Jeddah act in guidance of present laws and regulations. The regulations control household waste disposal practices, recycling, and even reuse. The city believes that God gave man the responsibility to secure and ensure the continuity of humankind. The regulations insist that the preservation of the environment is every citizen's responsibility without limitation or restriction. In guidance of Article 14, the city of Jeddah prohibits poisonous, radioactive, or hazardous waste into its territories including its waters and economic zones. All those involved in the production, transportation, storage, recycling, treatment, and final disposal of hazardous solid wastes have to comply with the city's procedures and controls.³¹³ The city also prohibits vessels from disposing of hazardous solid wastes, especially in territorial waters. The regulations encourage agencies to utilize recycling and reuse of wastes as well as requiring the agents generating or transporting waste to comply with all licensing requirements.³¹⁴ Persons engaged in waste management must also comply with Competency Agency guidelines regarding transportation, storage, treatment, and even disposal of solid wastes. The laws also dictate that in coordination with the Competent Agency, concerned agencies have to determine the necessary procedures towards the final disposal of wastes coming

³¹³ Zafar, Salman. "Waste management in Jeddah." (2013).

³¹⁴ Ouda, Omar et al., "Environmental and economic benefits of recovered paper, 3753-375

from excavation, demolition, or construction activities. All agencies have the responsibility of ensuring that all necessary precautions are in place to protect the environment and natural resources. Further, when burning solid wastes, the city stipulates that all smoke or gases resulting from the burning must be within the set limits as demonstrated in the KSA environmental standards. Plant owners must take all essential measures to make sure that there is no air pollutant leak beyond the stipulated limits. The city laws also require all agencies to prevent any discharge of hazardous solid waste into surface ground or waters. The regulations also require all parties to use the best available technologies and means of waste disposal to prevent and control degradation or contamination of soil. Any person or company that causes health or environmental risk through poor or outdated disposal or recycling technologies will remove and bear the costs arising from the pollution effects.

According to Jeddah's certification process to engage in municipal solid waste management, which includes collection, transportation, recycling, reuse, and final disposal, one must submit to the Presidency the details on vehicle fleet utilized in waste transportation. One also has to submit the detail of the solid waste storage unit, the technology used and extent of its viability and sustainability, disposal site preparation to prevent seepage as well as fire extinguishing system, and a safe contingency plan. To engage in recycling, the involved party has to present to Jeddah's municipal authorities the site of the recycling plant as well describe the treatment, sorting, and recycling stages, recycling method, as well as intended technology use. A private entity must also accurately identify the scope of work and what materials they intend to recycle. They also have to identify the residual non-recyclable wastes generated after the recycling process as well as how they intend to dispose of them. Some regulations guide the municipal government or private entities in the city of Jeddah in choosing a dumping or recycling site. One

requirement is that a dumping site must be far from populated areas. The lining of collection cells is also a requirement, which ensures that seepage of liquids into groundwater does not happen.³¹⁵ Landfills or any dumping site must have barriers around it and one entrance to a facility. Upon completion of a dumping or recycling site, one has to develop safety, health, and emergency plan as well as provide training to the employee on how to use the emergency equipment. Roads or paths to the site must also be paved to avoid dust. A landfill must also be covered to prevent insects and foul smell from the site.

The city of Jeddah also acts under the guidance of the Saudi Ministry of Environment, which regulates waste management, waste production, and activities such as sorting recycling in an effort to achieve environmental sustainability and maintain quality public health and human welfare. The ministry requires all manufacturers to have a moral, financial, and legal responsibility to reduce the environmental effects of their finished products. They have a responsibility of also ensuring the safe disposal of their products. National Center for waste management issues licenses as well as permits for waste treatment centers. Failure to comply with the set regulations such as lack of records on received and disposed of solid waste attracts fines from SR 5000 to 15000.³¹⁶ Falsified information also attracts a fine or imprisonment of not less than two months and one risks closure of the recycling facility. Workers working in dumping sites, landfills, or recycling plants are entitled to periodic medical checkups and failure to do so attracts a fine of SR 1000 to 5000. In event of any harm, the employer has the duty of taking care of the employee's fees. Failure to have an emergency plan as well as providing information on specifications for the construction of landfill, loading, and unloading sites also attracts hefty fines. Additionally, to engage in waste

³¹⁵ Gharaibeh, Emhaidy et al., "Evaluation of current municipal solid waste practice and management, 103-110

³¹⁶ Zafar, Salman. "Waste management in Jeddah." (2013).

generation activity, the city of Jeddah requires one to provide information to the Presidency. The information includes name, contacts, address, location of the facility, nature, as well as description of waste generating activities. The facility also has to describe its waste storage, treatment, and disposal activities.

6.3 Economic and environmental sustainability of waste management practices

Economic sustainability refers to solid waste disposal practices that help the city of Jeddah and KSA attain long-term economic growth without affecting social, environmental, and cultural aspects of the community negatively. Environmental sustainability, on the other hand, refers to MSW disposal or treatment practices that interact responsibly with the environment to escape depletion or degradation of natural resources such as soil in Saudi Arabia. The current waste management practices by the city of Jeddah have low economic and environmental sustainability. The city practices combustion of solid wastes or depositing them into landfills. Such practices pollute the environment and fail to promote economic and environmental sustainability. The deposition of household wastes or other organic waste within a landfill leaves it to go through biological, chemical, and physical processes. The processes depend on location temperature, moisture content, and pH. In the initial stage of the landfill system, solid waste and accumulation of moisture occur. After a while, sufficient moisture develops supporting an active microbial community. After the adjustment phase, the transition phase begins transforming the waste from an aerobic to an anaerobic environment. The organic content then converts to methane and carbon dioxide. At the maturation stage, the nutrients and substrates available begin to deplete as gas production drops, leading the leachate strength to stay steady. Landfill gas and wind-blown litter near represent pollution and emissions by landfills. In other words, landfills are

not economically and environmentally sustainable because methane and carbon dioxide, and other compounds from industrial wastes pollute the environment, leading to poor public health, which raises government and individual expenses on medical care. Jeddah's solid waste leachate is an environmental hazard as it contains hazardous and chemical contaminants. The solid waste also comprises of copper, zinc, which travel with leachate and end up degrading the soil, which is a natural resource. Landfill construction leads to landscape changes such as loss of habitats and displacement of fauna. The soil also suffers high levels of disturbance through the removal of topsoil. The landfill gas also contributes to the greenhouse effect, which damages the environment. Landfill gases are the leading causes of global warming. Gas pollution affects plants and animals. For example, lateral migration of the greenhouse gases beyond landfill boundaries leads to displacement of oxygen from soil, reducing animal and plant populations. Plants die due to air suppression while acidic gases contributing to acid rains, which also reduce photosynthesis and enzyme inhibition.

Apart from the above environmental impacts, landfills lead to negative socio-economic effects especially in public health due to landfill gas exposure. One may argue that current landfill sites have modern designs that reduce emissions but every emission gives rise to health concerns of people living and working near the sites. The contact to these gases through inhalation, ingestion, or direct contact may lead to abnormal child growth and cancer. The economic costs rise due to landfill pollution because the people of Jeddah will spend a significant amount of their income on treatment and medical bills. Landfill sites found in Jeddah do not support a green economy that minds the future generation through sustainable management of all-natural resources.³¹⁷ Landfill tax is also uneconomical as they increase the

³¹⁷ Zafar, Salman. "Waste management in Jeddah." (2013).

cost of sending waste to landfills. Other indirect costs arise due to landfill gas pollution. For example, sick citizens cannot work, which leads to low production and reduced Jeddah's GDP. Children experiencing asthma attacks due to landfill gas pollution also miss schools, requiring their parents/guardians to take their time off work. Such economic breakdowns lead to billions of losses, which slows Saudi Arabia's growth and development rate. Jeddah is, however, in the right direction as residents and authorities have started adapting recycling, reuse, and recovery of municipal solid waste. These practices are economic and environmentally sustainable because they protect future generations from pollution or global warming resulting from greenhouse gases emission. The city of Jeddah practices waste reduction, which is an effective way to limit negative health and environmental impacts.³¹⁸ One method utilized in Jeddah to help with solid waste reduction is incineration. Through incinerator plants, the city has the capability of converting heat energy to electricity. The method also prevents high-level emission of greenhouse gases into the environment, which promotes economic and environmental sustainability. The waste ash also helps in the production of construction materials such as bricks that help in road constructions, which a value addition to Jeddah's economy. The city starts waste reduction from household level to commercial level through the collection of waste bins. Waste reuse is another practice in Jeddah.³¹⁹ Waste scavengers, especially migrants to Jeddah city, practice waste reuse. They reuse different types of solid wastes such as bottles, books, and clothes preventing environmental pollution and soil degradation.

Jeddah also practices the recycling of solid waste. Apart from the environmental benefits of recycling, the process leads to dollar savings, realized when the council or companies avoid

³¹⁸ Ejaz, et al., "Environmental impacts of improper solid waste management, 379-387.

³¹⁹ Hakami and Seif, Household solid waste management in Jeddah city, Saudi Arabia, 1-10.

disposal or incineration costs. Recycling reduces the cost of sending solid waste to transfer stations for disposal. Another economic benefit is that recycling places a fewer burden on the economy. For example, recycling reduces the need for new raw materials and product imports. It is also less expensive to buy a recycled product as opposed to buying a new one. Recycling helps in environmental sustainability by helping in the utilization of solid waste that would have been disposed of, polluting the soil and air quality. Recycling in Jeddah has taught residents how to treat solid materials as valuable resources rather than waste. For example, there are paper-recycling companies in Jeddah. They break down the waste paper into fibers through pulping. Waste metals and glass are recycled into new raw materials. Composting is also environmentally and economically sustainable because the process involves the conversion of organic food wastes into compost. The compost is soil improvers that help in the long withstanding of droughts by plants. It also reduces the need for manufactured fertilizer, which lowers the quality of the soil³²⁰. Economic and environmentally sustainable practices evident in Jeddah are incineration, reuse, composting, and reuse of solid waste. The processes help reduce gas emissions that contribute to asthma, cancer, and other chronic illnesses. The rising medical bills require communities to spend much of their income on treatments instead of engaging in income-generating activities. The reduction of waste through reuse and recycling prevents the overutilization of natural resources, which helps with environmental sustainability. However, economic and environmentally sustainable practices such as recycling only account for about 10% of waste disposal and treatment management in Jeddah.³²¹ Over 70% of the city's solid waste ends up in dumpsites that are environmental and health hazards to residents living near these landfills.

³²⁰ Mu'azu, Nuhu Dalhat, Nawaf I. Blaisi, Ammar A. Naji, Isam Mohammed Abdel-Magid, and Ali AlQahtany. "Food waste management current practices and sustainable future approaches: a Saudi Arabian perspectives." *Journal of Material Cycles and Waste Management* 21, no. 3 (2019): 678-690

³²¹ Ouda, Omar et al., "Environmental and economic benefits of recovered paper, 3753-375

Many landfills in Jeddah have existed for decades and are almost reaching their full capacity. Smells from these sites have caused several illnesses and emissions of greenhouse gases, which cause global warming. Therefore, the city needs to invest in bioreactor landfills to help with the production of biogas or increase their recycling levels to ensure that their waste disposal practices are environmentally and economically sustainable.³²²

6.4 Weaknesses of the existing waste management legislations and practices in Jeddah

Jeddah's waste management legislation and practices work under the guidance of the 24 September 2001 Saudi Arabian national environmental legislation. The Presidency of Meteorology and environment, under Defense Ministry, was given the responsibility of supervising environmental affairs, including granting of environmental permits.³²³ However, when it comes to the municipal level, there are no proper legal regulations to allow coordination between municipal councils and Jeddah residents in the management of waste. The implementation of waste laws is also weak because the city management lacks adequate specialists responsible for waste management, planning, and reporting. The legislations fail to encourage a common scheme for collecting or recording data on the type of waste or recovery and recycling methods. The city also lacks systematic education to help educate residents in Jeddah on good waste disposal methods. In other words, the city of Jeddah lacks legal instruments to enforce waste management regulations, which makes it hard for the city to achieve local and regional waste collection goals.³²⁴ The city of Jeddah does not have enough landfills and has no incentive for environmental management system or cleaner production. The

³²² Khan and Zakariya, "Biodegradable waste to biogas, 101-113

³²³ Kulczycka, Joanna, Agnieszka Generowicz, and Zygmunt Kowalski. "Strength and Weakness of Municipal and packaging waste system in Poland." *Integrated Waste Management: Volume I* (2011): 79.

³²⁴ Lippitt, Paul, et al, "Planning for waste minimisation , 65-75.

city also deals with inadequate national policy and support. In addition, the city does not encourage Public-Private Partnerships (PPP) to assist the municipality in either solid waste collection or transportation.

Another major weakness in waste collection practices in the city of Jeddah is the lack of segregation of waste, especially at the household level. Segregation is a major step for the success of solid waste management in the city of Jeddah. The city also lacks an alternative to source segregation, which makes it hard for waste recovery technologies to work with unsegregated waste. The city can enhance waste segregation through increased awareness among the population of Jeddah instead of just collecting waste bins located outside residential and commercial buildings. To enhance such awareness, the city of Jeddah needs to involve private parties such as banks and media to help with spreading awareness. Increased awareness will lead to increased and active public participation in waste segregation and collection. Apart from increased awareness, the government has to implement all the laws provided by the Presidency of Meteorology to ensure that residents of Jeddah engage in proper waste segregation, collection, and transportation. In other terms, the current legislation and practices in waste management exclude the private sector as only the municipalities of the city deal with MSW.³²⁵ Municipalities and city corporations are under the public sector category and have many limitations. For example, the municipalities suffer from inadequate national supervision and as well as limited waste management equipment. The city has also not made waste handling a lucrative practice as the sector has low-profit margins because the government has not invested in tax incentives for companies willing to help with solid waste management in Jeddah. Jeddah waste management plans fail also to involve NGOs (Non-Governmental Organizations) who have the capability of

³²⁵ Gharaibeh, Emhaidy et al., "Evaluation of current municipal solid waste practice and management, 103-110

hiring waste pickers that provide door-to-door waste collection services for a fixed fee for every household.³²⁶ Annual grants can help to promote these organizations' financial resilience, allowing sustainable waste collection, handling, and transportation. The city of Jeddah has not failed to encourage the establishment of micro-enterprises such as recycling industries or service delivery industries, which may help in cleaning the solid waste that ends up polluting the environment after disposal into the city's landfills.

A major weakness in waste collection and handling practice is the lack of segregation of waste or source separation. Waste pickers and households dispose of waste without separating organic and inorganic materials, which has become a major problem in the city of Jeddah. Lack of segregation practices has reduced waste recycling and reuses practices in Jeddah, which only accounts for about 10%.³²⁷ The remaining 90% involve the disposal of waste into landfills and waste burning, which end up polluting the environment.³²⁸ Segregation of waste would make waste transportation to recycling units, energy recovery, or landfills very easy and efficient. The city also places similar colored bins in residential and commercial buildings. Instead, the municipal council needs to put different colored bins to encourage waste separation. One bin needs to carry organic and food wastes while the rest carries paper, glass, and textile wastes. However, currently in Jeddah, households put all their waste in one bin, which has made reuse and recycling practices to be very low in the area. Such methods require constant monitoring by the private sector or municipality to ensure the correct disposal of waste. However, the municipality conducts inadequate supervision on matters of waste management, which has made

³²⁶ Hakami and Seif, Household solid waste management in Jeddah city, Saudi Arabia, 1-10.

³²⁷ Kulczycka et al., "Strength and Weakness of Municipal, 79.

³²⁸ Kulczycka, Joanna, Agnieszka Generowicz, and Zygmunt Kowalski. "Strength and Weakness of Municipal and packaging waste system in Poland." *Integrated Waste Management: Volume I* (2011): 79.

the city of Jeddah struggle with waste management.³²⁹ Segregation at the source is easy, less time-consuming, and cost-effective but the current waste disposal practices in Jeddah only focus on the reduction of waste instead of increasing efforts on waste reuse and recycling.³³⁰

The government of Saudi Arabia spends little or no time creating awareness on the benefits of different waste disposal techniques. The measures and legislations fail to target early education to ensure that children understand the needs of a clean environment. The waste management policies in the city fail to utilize advertisements and social networking websites on issues regarding SWM. The city's authority passively participates in the implementation and advancement of solid waste management. There is inadequate monitoring of public and private sector industries in ensuring that they follow the General Environmental Regulations and Rules for Implementation. The city of Jeddah has done little to amend or improve such regulations to ensure sustainable implementation and execution of its recommendations. Additionally, there is a limited annual waste management survey in the city of Jeddah. The city also lacks a comprehensive database on the amount of waste generated, recycled, recovered, and disposed and the available data is out of date and mainly conducted by private entities. Division of data into localities within the city of Jeddah is also lacking, which makes it hard to have a broader understanding of the solid waste management problem in Jeddah.

6.5 Relationship between Urban Planning and Waste Management Practices

Waste management has become a problem for rapidly growing cities like Jeddah. The world today faces unsustainable production and consumption patterns, which give rise to wastes,

³²⁹ Hakami and Seif, Household solid waste management in Jeddah city, Saudi Arabia, 1-10.

³³⁰ Zafar, Salman. "Waste management in Jeddah." (2013).

which has the potential of harming people's health and the environment. To ensure proper waste management, Jeddah has to review its urban planning because solid waste disposal activities have a direct influence over Jeddah's development possibilities. In other terms, urban planners have a high influence on solid waste disposal strategies. Jeddah is the second-largest city in Saudi Arabia and a major urban center in the western region. However, the city is facing challenges in waste management due to its lack of services and infrastructure.³³¹ The rapid population increase in the city has led to planning challenges, leading to the proliferation of dumpsites, which degrade the quality of the urban environment the city's urban plans have been overtaken by the city's rapid development. In addition, the city's urban planning process has led to poor environmental, economical, and social outcomes because Jeddah's urban planning process is ineffective.³³² The city's planning depended on blueprint plans by overseas experts who had inadequate local knowledge of Jeddah's culture. The city requires a responsive system to address the current solid waste management problem.³³³ With population increase anticipation, the city expects to continue experiencing challenges of sustainable development.³³⁴ Waste management in urban areas plays a crucial role as they determine the activities of the next generations. Any urban system cannot be sustainable if it generates more wastes that the environment can assimilate.³³⁵

³³¹ Ajaj, Mohammad Hamzah Abdullah. "The role of local municipal branches in planning, developing and managing urban growth in Saudi Arabian cities: a case study of the city of Jeddah." PhD diss., Newcastle University, 2014.

³³² Lippitt, Paul, et al , 65-75.

³³³ Lippitt, Paul, et al, "Planning for waste minimisation , 65-75

³³⁴ Ai, Ning. "Challenges of sustainable urban planning.

³³⁵ Ajaj: a case study of the city of Jeddah," 54.

Many cities fail to involve city planners in waste management, which has seen many cities such as Jeddah focus on short-term policies and impacts.³³⁶ They fail to understand that waste management has a direct link with economic development, land use, as well as environmental planning. City planning interacts with waste management right from the source of waste generation, which includes residential and commercial buildings, making Jeddah concentrate on collecting waste bins outside residential and commercial buildings to reduce the amount of waste. It means residential and commercial city designs affect waste management practices within a given city. Therefore, city planners have the skills necessary for efficient waste management. City planners have a clear understanding of the city's demographic and economic structure. They engage in community or infrastructure planning, and waste management is among such plans. The city of Jeddah generates massive amounts of waste from households and businesses, which poses a great urban planning challenge. The city leaders in Jeddah have to come up with a plan on how to collect, sort, transport, and dispose of the city's solid waste. To do so, they must collaborate with other leaders and institutions such as the city planners. All city planners must have a clear understanding of the city's waste management practices to note where and how waste management and city planning interact.³³⁷ Therefore, urban planners must come up with a proper waste facility site that would help Jeddah reduce its increasing solid waste. The siting of any waste management facility has a direct impact on surrounding communities' economic success and quality of life. For example, a comprehensive plan on the city of Jeddah must include a strategic location for a landfill. The city planners have to account for unpleasant smells as well as a reduction in property value near the landfill site. Therefore, any urban plan has to ensure that landfills are located where they will have minimal impact on the surrounding

³³⁶ Ejaz, et al., "Environmental impacts of improper solid waste management, 379-387

³³⁷ Lippitt, Paul, et al, "Planning for waste minimisation , 65-75

communities. One such consideration is locating them away from residential areas to reduce health impacts that result from landfill gases such as asthma and cancer³³⁸. Planners have the duty of ensuring that there is safe and equitable siting of waste management facilities. City or urban plan determines how easy the residents will deal with waste. It means designing buildings for easy collection and disposal of waste. The urban planners have to plan for a minimized number of times, proper location of elevators, and waste space to ensure that waste pickers find it easy to eliminate the city waste. City design has to ensure a reduction in friction when it comes to garbage collection by also ensuring proper infrastructure such as access roads to all residential and commercial buildings across Jeddah. Modern city planners are concentrating on drop-off kiosks to minimize the need for trucks to every building. The design of city streets has to ensure that street residents easily drop off their recyclables or redesign public space for easier movement of waste.³³⁹

The above information is a clear indication that urban planning has a direct association with waste collection and disposal practices. Poorly planned cities experience high levels of waste accumulation because even trucks find it difficult to navigate the narrow city streets or slums, which increase pollution levels.³⁴⁰ City planners engage in the management of land resources as well as regulation of its use. Landfills or recycling plants require land, which means setting up of landfill must involve city planners for them to come up with a suitable location. Therefore, urban planners have a direct interest in any aspect of waste production. They also dictate the formulation and implementation of waste disposal sites and options. Solid waste disposal activities have a strong influence on urban development possibilities. The city planners

³³⁸ Ejaz, et al., "Environmental impacts of improper solid waste management, 379-387

³³⁹ Ibid, 53.

³⁴⁰ Ajaj, Mohammad, 54.

have the authority of rendering sites hazardous and undevelopable. The current solid waste landfills in the city of Jeddah are nearing full capacity while they continue to pollute the city's environment. Population in the city is also on the rise, which means that solid waste will increase due to increased consumption. It means that to eliminate the increasing wastes, cities have to rethink the way they dispose of wastes, which means new urban designs that favor easy waste collection and disposal. The landfill also requires land use and the current rise in population have increased the need for land.³⁴¹ Therefore, landfills and development projects will be competing for space. To build a sustainable city, urban planners must ensure that Jeddah has adequate land space that will favor future development in the waste management system. Conclusively, urban planning and waste management practices have a direct relationship. City planners in Jeddah have to transform the current waste management practices because they are cost-burden and engage in long-term development strategies that include waste management into sustainable urban planning programs.³⁴²

6.6 Impact of government failures and market externalities on solid waste management

Government failure in waste management is evident all over the Kingdom of Saudi Arabia. The impact of these failures is immense to a point that the Saudi Shura Council has noted the loss of public resources due to wasteful Ministry of Municipal and Rural Affairs (MOMRA). In February 2018, the council criticized the ministry for wasting government resources, a rare criticism from an appointed body to a Saudi government institution. The rebuke is a clear illustration of the gap between the state aspiration as recommended by Crown Prince Mohamad

³⁴¹ Lippitt, Paul, et al, "Planning for waste minimisation , 65-75

³⁴² Gharaibeh, Emhaidy et al., "Evaluation of current municipal solid waste practice and management, 103-110

Bin Salman and the capacity of disempowered Saudi governance structures such as MOMRA.³⁴³

The lack of cooperation and unity between the municipal governance and local governance is a failure.³⁴⁴ The centralized power in KSA's municipalities does not support the local authorities, which leaves the city and residents at risk of poor hygiene and health due to solid waste pollution. The current system in municipal and local authorities in KSA has failed to resolve development problems including a proper waste management system to handle all the cities' solid wastes. Simple services such as waste management have become a problem to the local government. In 2017, people died in Jeddah, Saudi Arabia's second-largest city, because of floods. The floods cause such damages due to poor government planning and disposal of solid wastes that end up blocking the destroying few available local drainage infrastructures.³⁴⁵

Municipal authorities' failure led to 4 deaths in Jeddah, an indication that any failure including in waste management lead also to deaths. The poor maintenance of Jeddah landfills leaves solid waste at risk of finding its way back to residential areas through floods. The city residents are at risk of waterborne diseases such as cholera and asthma/cancer due to toxic fumes emanating from the landfills. Poor urban planning is also evident in Jeddah due to the government's failure to involve local authorities.³⁴⁶ For example, after the killing of four people in Jeddah by floods, the Saudi government engaged in new projects to avoid such damages in the future. However, instead of involving the local and regional authorities, MOMRA gave the tenders to Aramco, which is Saudi Arabia's national oil company. Entrusting Aramco with

³⁴³ Abdulaal, W. "Municipal councils in Saudi Arabia: Context and organization." *Journal of King Abdulaziz University: Environmental Design Science* 1 (2006): 1-25.

³⁴⁴ Montagu, Caroline. *Civil society in Saudi Arabia*, 2015.

³⁴⁵ Lippitt, Paul, et al, "Planning for waste minimisation , 65-75

³⁴⁶ Abdulaal, W. "Municipal councils in Saudi Arabia: Context and organization," 1-25.

management and overseeing of local infrastructure is a failure by the Jeddah's municipal authorities, which has left the residents of Jeddah struggling with annual floods. The failure of government impacts the city residents the most as they are the ones left to fight diseases, pollution, and destruction of properties. The municipality of Jeddah and Aramco blame each other for the failures in Jeddah projects, which leave the city grappling with unresolved infrastructure issues.³⁴⁷ The main problem is the centralization of decision-making in the municipalities, which has led to the overlapping of authority at regional and local levels. Vision 2030 insists on Saudi Arabia's sustainability including in cities' programs.³⁴⁸ One of the sustainable development goals is to reduce all types of pollution in KSA to improve the urban scene in Saudi cities. However, it seems that city residents will have to wait longer to enjoy clean air, water, and unpolluted soil because the regional and local institutions are inefficient. The local authorities, instead of focusing on delivering services to the residents of Jeddah, face confusing by-laws issued by different ministries, confusing hierarchy, and legal authority. The inefficiency has left Jeddah fighting air pollution, solid waste pollution, and flooding, which puts their health at risk of asthma and cancer.

The local and municipal agencies have also failed to correct the market externalities in waste management. The government has a duty of controlling the market to control solid wastes such as plastics in the environment. The KSA municipalities have failed to invest in recycling programs that ensure consumers and retailers recycle their plastics or paper.³⁴⁹ With the lack of

³⁴⁷ Ejaz, et al., "Environmental impacts of improper solid waste management, 379-387

³⁴⁸ Abdulaal, W, 1-25.

³⁴⁹ Fisher, Linda R. "Multi-market impacts of market-based recycling initiatives." *Journal of the Air & Waste Management Association* 49, no. 9 (1999): 1089-1095.

market for plastic or solid waste recycling in Jeddah, the consumers and suppliers have over-exploited the solid waste without any proper disposal. Therefore, the increase in solid waste in the city of Jeddah is a representation of market failure. The population increase in Saudi Arabia's cities has led to a rise in solid waste. However, most of the solid waste ends up in landfills, which pollutes the environment. Only about 10-14% of these solid wastes get recycled.³⁵⁰ Waste comes with other economic costs. For example, plastic clean-up and landfill processing or treatment require millions, illustrating negative externalities resulting from failure to control the plastic market. The city of Jeddah also cannot feasibly recycle glass because the government has invested very little in glass recycling centers, which would make recycling profitable. Therefore, most of the glass bottles sold in Jeddah end up at the dump.³⁵¹ Toxic fumes from toxic wastes and contamination of groundwater due to poor landfill designs lead to diseases and deaths but the price of these wastes never accounts for such externalities. When an industry pollutes the city's air by throwing glass bottles in a dump, the market prices do not account for the cost to the municipality in cleaning the solid waste from the dump. The cost of disposing of solid waste does not fall on the producer, but the municipality. The producer of the waste enjoys increased profits while the city incurs loss due to the cost of disposal.

6.7 Impact of urban economic development of solid waste management

Many world cities including Jeddah are experiencing an increase in population, which means that solid waste accumulation is also on the rise. However, unlike the past, most of the

³⁵⁰ Abdulaal, "Municipal councils in Saudi Arabia, 1-25.

³⁵¹ Ibid, 1-25.

current wastes, which comprise of e-waste, medical wastes, and industrial waste, meaning that cities cannot continue using simple waste management techniques such as burying and burning of wastes. In other terms, the current increase in the amount of solid waste and composition of these wastes requires sustainable urban economic development. The waste agencies have a duty of ensuring economic sustainability through cost-saving in waste disposal by making sure that the development of waste systems leads to the minimization of residual waste. Urban development needs to encourage solid waste treatment options such as reuse, recycling, and recovery. Additionally, these treatment options must be cost-effective by ensuring that a city recycles more solid waste than being disposed of. It means that KSA and the city of Jeddah need invest in appropriate practices, infrastructure, and waste management equipment. Further, urban economic development must ensure that the investments lead to infrastructure and waste services that are affordable to operate and maintain even in the long-run. Urban development also needs to encourage investment in local technologies.³⁵² A sustainable urban economic development of waste management leads to future preservation because it involves partnerships among local and national agencies, which leads to national-local coordination on urban development. In Jeddah, rapid urbanization has led to an increase in the generation of solid waste. The lack of coordination between the local and national governments on waste management has led to confusion and poor implementation of projects. The city is currently dealing with commercial and industrial wastes as well as construction and demolition waste. Such rise requires waste management solutions. Urban development on waste has to focus on treating waste in an environmentally and socially acceptable manner because inefficient waste treatment increases environmental and health hazards, leading to economic losses. In the city of Jeddah, local

³⁵² Gharaibeh, Emhaidy et al., "Evaluation of current municipal solid waste practice and management, 103-110

authorities lack the resources and capabilities for effective municipal solid waste management. The national government bypasses local authorities when it comes to urban development, which makes the city end up relying on short-term solutions that involve the partial collection of urban waste and disposal of waste into unsanitary dumpsites and landfills. These methods lead to the spread of wastes into the city's environment, which increases greenhouse gas emissions and aggravated difficulty in final waste treatment.

An integrated waste management system can be profitable for the city through the recycling of wastes. It also boosts a city's reputation as well as preserving the environment as opposed to landfills that release toxic gases leading to the destruction of the ozone layer. It can also reduce the costs of running the city through the conservation of natural resources. However, the city of Jeddah experiences several negative impacts due to improper handling of solid waste management resulting from poor urban planning.³⁵³ The waste collected from the city is transported using open trucks and dumped in unhygienic ways. Waste bins are also a great concern as they lead to the spread of waste in the city, which end up blocking drains and sewers. For example, in Jeddah, the municipality is struggling with floods, which have even caused death to innocent residents. The floods lead to unhygienic conditions in the city of Jeddah. The open solid waste dumping is giving room for insects such as mosquitos to thrive, causing the spread of diseases such as malaria. Urban development on waste must focus on zero solid waste in the city because the waste is degrading the urban environment. The city government does not offer separate waste collection facilities. Such poor waste disposal practice is dangerous as broken glasses, needles, and dangerous chemicals end up in the landfills, which puts the life of waste scavengers at risk. The transport of waste relies on heavy trucks that end destroying the city's

³⁵³ Lippitt, Paul, et al, "Planning for waste minimisation , 65-75

infrastructure. Locals or city residents do not separate wastes, which leads to the mixing of organic and inorganic wastes, making recycling in the city a very difficult task. The water bodies in the area end up receiving most of the poorly dumped solid waste, which threatens human and aquatic life. Some city residents depend on waste for their livelihood, which means proper waste management can create income for the unskilled residents in Jeddah. The only way to do so is by making sure that urban development includes sorting and recycling plants, which will lead to a cleaner city. Recycling will reduce health risks for scavengers and families living near landfills or open dumpsites.

Improved urban development on waste management will ensure the health and safety of city residents. Poor waste management, as evident in Jeddah, causes an increase in public health and medical costs. The city experiences low productivity due to sick days from work. Properly treated landfills will ensure a decrease in health risks such as malaria. Proper urban development will lead to poverty alienation, as families will engage in the reuse and recycling industry. Such industries are leading sources of job and employment opportunities. Jeddah city's urban development on waste management, such as the recycling industry, needs to engage the waste pickers/scavengers to increase social security as well as reduce cases of child labor. Poor waste collection and disposal in the city of Jeddah leads to odors and rundown of public landscapes. Properties and resources near the sites and landfills lose their value from an economic perspective. Therefore, the urban development of waste management has a direct impact not only on the public amenity but also on the value of city resources. Jeddah city experiences floods, which is a sign of drainage blockage or poor urban planning.³⁵⁴ City solid waste finds its way to the drainage system because the city has little recycling and reuse infrastructure. The poor

³⁵⁴ Lippitt, Paul, et al, "Planning for waste minimisation , 65-75

planning is a result of poor coordination between the municipal government and the national government. To attain a sustainable waste management system, the local and municipal governments need to encourage public participation because some issues such as sorting and recycling rely on the support of households.³⁵⁵

³⁵⁵ Hakami and Seif, Household solid waste management in Jeddah city, Saudi Arabia, 1-10.

7 NATIONAL AND MUNICIPAL AGENCIES PRACTICES TO OVERCOME THE SOLID WASTE MANAGEMENT CHALLENGES IN JEDDAH, SAUDI ARABIA

7.1 Introduction

The large cities in KSA such as Riyadh, Jeddah, and Mecca produce about half of all waste produced in the kingdom. The national and municipal agencies on waste management have established less or no programs on sorting, recycling, or disposing of waste using proper and safe methods. Further, the coordination between the two agencies is low because the country lacks an organized system to deal with the MSW. Most of the solid wastes from these cities go to landfill sites of each municipality. However, few initiatives are aiming at recycling plastics, paper, steel, and aluminum. The municipalities organize waste management while the private sector engages in technical implementation. The problem is that the municipalities spend their resources in the collection and transportation of waste and only 5 percent goes to treatment and landfilling. The national and municipal agencies are working hard to increase waste management facilities such as transfer stations and sorting plants to help in the separation of recyclable materials. Local companies mainly get the contracts to construct transfer stations but the problem in KSA is that many available stations are out of service while others lack full utilization. The agencies are trying to invest in simple sorting plants in major cities such as Jeddah to help in the separation of saleable recycled materials. KSA is trying to manage waste in accordance with the international standard .

The national and municipal agencies are facing high waste volumes due to rapid urbanization and cultural practices such as food wastefulness. The agencies are working hard to come up with MSW management solutions. For example, they target to divert all solid waste

away from landfill sites. The agencies are willing to do more to crack down on solid waste, which has led to new legislation and initiatives to tackle industrial, medical, and electronic waste. One area of focus is education and support for home recycling practices. The agencies are also directing resources to Cleantech technologies and green waste management practices. The aim is to ensure solid waste such as food, organic, paper, or plastics from individual or community waste containers end up being recycled, recovered, or reused instead of disposing of it in open landfills or dumpsites. Recycling, reuse, and energy recovery are at an early stage but they continue to attract attention. The increase in the informal sector has increased waste sorting and recycling. Due to the high content of organic content in MSW, composting is also gaining interest. The national agency is also aiming at establishing a national recycling company to support domestic recycling to raise the current 10% to a higher percentage by 2030.

7.2 Industrial Waste Management Practices

Saudi Arabia's Vision 2030 targets 100% diversion of municipal solid waste from landfills. The country, including the city of Jeddah, also aims at diverting 60% of construction or demolition waste from landfills as well as 85% of industrial waste.³⁵⁶ The city's plan includes establishing a circular economy based on enriching the earth using compost and increasing recycling rates. The plan is to reduce pollution and health risks associated with toxic fumes and odor from landfills including CO₂ that are of high risk to residents' health.³⁵⁷ The country sells thousands of tons of copper and aluminum scrap metals to India and Asia. When it comes to

³⁵⁶ Ouda, 2541.

³⁵⁷ Picó, Yolanda, Julian Campo, Ahmed H. Alfarhan, Mohamed A. El-Sheikh, and Damià Barceló. "A reconnaissance study of pharmaceuticals, pesticides, perfluoroalkyl substances and organophosphorus flame retardants in the aquatic environment, wild plants and vegetables of two Saudi Arabia urban areas: Environmental and human health risk assessment." *Science of The Total Environment* 776 (2021): 145843.

industrial waste such as hazardous petrochemical waste, the city of Jeddah is only at 20% treatment capability. KSA even prefers sending some industrial waste to the United States for treatment before shipping back to the Kingdom. The main practices of industrial waste disposal in Jeddah, Saudi Arabia include burning, burying, and recycling. Out of the total industrial solid waste produced in Jeddah, burning ranges from 25% to 10%. The percentage of burying keeps fluctuating from 40 to 35% while recycling of industrial waste ranges from 34% to 50%. However, burning and burying have adverse effects on the environment, which has made national and municipal agencies increase the level of segregation and recycling.³⁵⁸ The city of Jeddah is working hard to improve industrial waste management by setting up recycling bins. The city is also engaging in scrap metal recycling, electronic, food waste, glass, and paper recycling. Recycling has helped in the disposal of hazardous, compostable, and non-hazardous waste. Saudi Arabia also understands that to deal with industrial waste effectively and efficiently, an integrated waste management and waste recycling activities in cities like Jeddah are essential. Jointly, the national and municipal agencies are working to help execute an industrial waste management strategy for Jeddah to attain the 2035 recycling objectives. The aim is to recycle over 80% of industrial waste. The first initiative is to recycle industrial scrap metals into building materials for road and housing projects. The agencies have also invested in the construction of a sorting facility to eliminate waste bins.³⁵⁹ The municipal agencies are also replacing single bins with two bins with green bins carrying plastics, paper, glass, or metal cans while black bins comprise organic industrial waste, residues, and food components.

³⁵⁸ Ouda, O et al.. "A case study of sustainable construction waste management, 2541-2555.

³⁵⁹ Blaisi, Nawaf I. "Construction and demolition waste management in Saudi Arabia: Current practice and roadmap for sustainable management." *Journal of cleaner production* 221 (2019): 167-175.

Municipal agencies tasked with waste management in Jeddah understand that a circular economy that puts value on reuse instead of single-use can save Jeddah from solid waste pollution. They understand that recycling these industrial wastes will reduce gas emissions and save the national and municipalities money. To overcome pollution by industrial waste, Jeddah's municipality is working hard to reuse and promote a circular economy. In guidance of Aramco's technology, the city is improving its infrastructure to help it deal with the industrial waste.³⁶⁰ Industrial waste is hard to treat and has adverse impacts on soil fertility. To minimize such negative impacts, Jeddah city turns polythene recovered from wastewater into plastic products such as cable pipes and flowerpots. High-density polythene is difficult to recycle but through an innovative approach, Saudi Arabia is working hard to re-use it and minimize environmental impacts.³⁶¹ Recycling polythene has enabled the city to avoid pollution that results from its burning. There are efforts to develop facilities that will help in converting industrial waste into energy.³⁶² Such successes will be a game-changer in Jeddah's chemical industry as the city aims at providing a sustainable and reliable solution for industrial waste management.

7.3 Cooperation between local and central government on solid waste management

The cooperation between local and central governments on waste management is very limited in KSA. First, the municipal council has limited responsibilities as the central

³⁶⁰ Sabbahi, Dania A., Hesham M. El-Naggar, and Mohammed H. Zahran. "Management of dental waste in dental offices and clinics in Jeddah, Saudi Arabia." *Journal of the Air & Waste Management Association* 70, no. 10 (2020): 1022-1029.

³⁶¹ Ejaz, et al., "Environmental impacts of improper solid waste management, 379-387

³⁶² Sadeq, Y., A. S. Nizami, S. A. Batool, M. N. Chaudary, O. K. M. Ouda, Z-u-Z. Asam, K. Habib, M. Rehan, and A. Demirbas. "Waste-to-energy and recycling value for developing integrated solid waste management plan in Lahore." *Energy Sources, Part B: Economics, Planning, and Policy* 11, no. 7 (2016): 569-579.

government decides upon many municipal issues as established by the Law of Municipalities. The duties do not give them all the power to decide on all city issues. Each local agency, especially in waste management is answerable to the Central Ministry. Therefore, the cooperation between the local and central government exists in Jeddah but at a very limited level.³⁶³ The municipal council reviews the municipality budget, and propose projects .³⁶⁴ The local authorities have less capacity to address the city's needs in waste management. The city lacks the presence of high levels of administration and organization in waste management. The absence of central government in the management of waste affairs in Jeddah has led to low accountability and transparency. There are no developments of national waste institutions in Jeddah due to the bureaucratic administrative practice, which has led to delays in the delivery of waste management projects.

The central administrative method in KSA is impendent to an integrated system of waste management. To enhance more cooperation, the central government needs to practice decentralized decision-making.³⁶⁵ Decentralization will help in clarifying the different roles of levels of government, making it easier for them to conduct their duties. It will also help in the fair distribution of financial revenue leading to innovation. The coordination between the central and local government will increase the confidence of local administration due to clarity and transparency. In KSA, cooperation between the local and national government exists. However, a problem exists in their form of cooperation. In KSA, the central government designs and formulates strategies and policies while the local government does the implementation. Such cooperation is weak because only the central government participates in decision-making.

³⁶³ Ibid.

³⁶⁴ Lippitt, Paul, et al, "Planning for waste minimisation , 65-75

³⁶⁵ Montagu, Caroline. *Civil society in Saudi Arabia*, 2015

Another form of cooperation between the local government and the central government of Saudi Arabia is in the appointment of council members. The central government has established municipal councils that represent people in municipalities.³⁶⁶ They report to the central government the needs of the city's residents. However, municipal councils have no primary role, which leads to confusion. In addition, the central government appoints half the members of the council, which has led to the conflict of interests, blurred vision in urban development. The success of Jeddah's local government depends on the available support from the central government. The central government of Saudi Arabia is making efforts to establish local administrative bodies and better clarity for policies. The government aims to decentralize decision-making in waste management to help the ministry operate smoothly. The central government decentralization policy also aims at helping and improving local authorities as well as empowers them to carry out their duties effectively. The visible problem in Jeddah is that during the implementation of waste management policies, different laws and policies exist, which lead to delays and duplication.

To increase cooperation between local and central government, KSA established the Ministry of Municipal Rural Affairs (MOMRA) to help in the provision of technical support for the municipalities. However, less technical support is provided to cities by MOMRA.³⁶⁷ It means that the control of local activities such as waste management rests in the hands of top central government officials, but they provide little practical support towards the implementation of recycling or reuse programs. Jeddah local authorities are also suffering due to centralized financial decision-making. The decision on financing waste disposal projects comes from top to

³⁶⁶ Ibid., 2015

³⁶⁷ Montagu, Caroline. *Civil society in Saudi Arabia*, 2015

bottom, including annual budget matters. The senior management of the central government in KSA makes all the crucial decisions, which leads to delays and higher costs of implementation of waste management projects. In general, the management of KSA cities, including Jeddah's infrastructure on waste management, is under different government agencies of the Ministry of Municipal and Rural Affairs. However, all these bodies lack coordination and permanent organization. For example, in recent years, the Kingdom has been setting and giving companies such as Aramco contracts to deal with sanitation and water projects. However, under the ministry's structure, there is nobody responsible for the coordination of all government agencies. A good example is a construction of a drainage system in Jeddah by Aramco. The central government did not involve the local government during the construction of the drainage system to reduce levels of flooding in Jeddah. Today, the city is still dealing with floods as solid wastes continue to block the drainage system. However, cooperation between local and central government would have combined the issue of flood with waste management, thus coming up with a coordinated approach towards flooding. Aramco is a private company dealing with oil and has limited knowledge about Jeddah. Therefore, to eliminate the problem of flooding and solid waste menace in Jeddah, the central government needs to cooperate with the local authorities because they have a better understanding of the sanitary problems facing Jeddah residents. In other words, a big city like Jeddah, a major municipality in Jeddah relies on central authorities in the Ministry of Rural Affairs regarding any urban development project including recycling or sorting of wastes. Independence in decision-making in the city is limited to few issues at the operational level. The 1975 Ministry represents the central government in all the activities in the municipalities, mainly activities relating to the planning of the city.³⁶⁸ It enjoys all the powers

³⁶⁸ Lippitt, Paul, et al, "Planning for waste minimisation , 65-75

and responsibilities to ensure local authorities' good performance. The Ministry improves the sanitary situation in Jeddah by holding consultative meetings with local municipal branches and councils. Therefore, when it comes to waste management in KSA, local authorities participate in project implementation but are absent in original decision-making. To ensure total cooperation, the central government of KSA needs to practice decentralization and involve local governments in the decision-making process instead of only engaging them during the final stage of a waste management plan.³⁶⁹

7.4 People's attitudes and awareness towards solid waste management practices

Solid wastes have adverse effects on the environment and public health, which requires advanced management practices to ensure clean and healthy surroundings. Waste management originated in Greek as they faced an increase in population, and limited space, which necessitated more than basic practices in waste management. A rise in population made sanitation practices difficult, which is evident in KSA, Jeddah. The population is on the rise and solid waste is still accumulating in landfills and dumpsites. The best way to deal with the solid waste in Jeddah is to turn to knowledge, attitudes, and awareness of the residents to involve them in the protection of their health and environment. In Jeddah, awareness of solid waste management is very low, which alters people's attitude towards proposed disposal practices. In the city of Jeddah, people engage in overbuying, especially food items during holiday celebrations.³⁷⁰ Due to lack of awareness, they engage in overbuying of food products as well as making poor product choices. The city's culture and attitude allow them to overcook and

³⁶⁹ Montagu, Caroline. *Civil society in Saudi Arabia*, 2015

³⁷⁰ Desa, Asmawati, Nor Ba'yah Abd Kadir, and Fatimah Yusooff. "A study on the knowledge, attitudes, awareness status and behaviour concerning solid waste management." *Procedia-Social and Behavioral Sciences* 18 (2011): 643-648.

oversupply food products, which illustrates poor household planning.³⁷¹ Poor food dumping is rampant, with the contribution of such behavior being due to inadequate knowledge and awareness on the importance of recycling among public and government officials. The people in the city also lack knowledge and awareness on the environmental impacts of recycling or sorting of wastes before dumping.³⁷² The people of KSA, including Jeddah, have low awareness of how solid waste can be a source of income. However, the shortage of recycling industries in Jeddah is an illustration that people have limited awareness of recycling benefits. There are opportunities for recycling industries in Jeddah due to the accumulation of solid wastes such as paper, plastic, and metals as the population continues to rise. According to Arab League, Saudi Arabia can save over 500 million SR if the country engages in the recycling of paper, plastic, and iron.

The government in KSA has continued to encourage the recycling of solid wastes in line with its Vision 2030 but the recycling attitude even in big cities such as Jeddah is not active or obvious. It is not a daily habit, which illustrates a lack of knowledge and awareness. The majority of residents are aware that recycling solid waste is beneficial but only a small percentage recycle or reuse their household solid waste. Surveys indicate that about 50% of residents in Jeddah do not engage in recycling at all. The biggest challenge is the lack of recycling containers near their residents. The majority are aware that recycling is healthy and essential to the environment, but the lack of recycling facilities limits people's attitude towards daily recycling of solid waste. There is a high need to educate the city's residents on recycling especially in this era of population increase and economic challenges.³⁷³ To promote recycling

³⁷¹ Lippitt, Paul, et al, "Planning for waste minimisation , 65-75

³⁷² Desa, Asmawati, et al.,. "A study on the knowledge, attitudes, awareness status and behaviour concerning solid waste management." (2011): 643-648.

³⁷³ Ai, Ning. "Challenges of sustainable urban planning.

behavior and attitude, KSA must invest in early education to ensure that children learn the importance of recycling during their school years. Doing so will encourage sustainable solid waste management as the children will transfer what they learn in schools to the cities, thus raising awareness.

The major contributor to low awareness in the city of Jeddah is that the decision-makers in local and central government continue to encourage burning and burying of solid wastes, which are outdated disposal practices. The young generation is always on social media platforms such as Snapchat, Twitter, Facebook, and Instagram but the government and local municipality have not tried to reach this generation through the platforms.³⁷⁴ The agencies need to make recycling attitude a normal behavior among the young generation, which will require increased awareness campaigns through social media platforms. Jeddah city has no clear strategies or policies on solid waste management. The major issue is that the city lacks sufficient MSW data, which makes it hard to come up with sustainable management practices. The government or agency's' inadequate awareness practices have led to lowered people's attitudes and lack of awareness, as well as uncertainty in solid waste management acceptability. The city also lacks clear legislation on solid waste management, which has left city residents without clear guidance on how to treat solid wastes. The residents are also unaware of recycling benefits due to the lack of organizations dealing with paper recycling.³⁷⁵ The local municipality and councils have people with low experience in recycling, which makes it difficult for them to educate the local masses on recycling benefits. Another barrier to awareness in Jeddah is the poor infrastructure that supports the recycling of solid wastes. This results from a lack of accurate information on

³⁷⁴ Desa, Asmawati, et al., 643.

³⁷⁵ Desa, Asmawati, et al., 643-648

solid waste as well as a lack of clear instructions on how to handle solid household wastes. Due to low recycling awareness, the city has low demand for recycled products as people are after new products, which has lowered the growth of waste recycling in Jeddah. KSA is oil-dependent and uses petroleum for energy production. This hinders people's dependence on biogas or converting solid waste into energy, as there is no motivation for such recycling practices. In Jeddah, the laws do not support the separation of waste or proper treatment of solid waste by companies or agencies tasked with waste collection and disposal in Jeddah.

In Jeddah, media campaigns on recycling or other proper ways of waste disposal are absent. Almost every household in Jeddah has a television or radio, which means any information aired through these devices can help in raising awareness on correct ways of treating solid wastes. However, local and central governments fail to involve the media in such campaigns. There is a need to engage the media in Jeddah to help with spreading awareness on the importance of sorting, reuse, and recycling solid wastes. The city also needs to encourage cooperation between local and private agencies when it comes to solid waste management as private companies will help in raising awareness on the importance of recycling. The encouragement of the private sector in waste management will help break the interrelationships barriers among the local residents, local authorities, and central government. Such barriers lead to poor communication of policies on solid waste management as well as poor coordination, which limit information sharing, leading to low demand for recycled products.

7.5 Proposed Sustainable Solid Waste Management Practices

Jeddah city has given municipal solid waste management serious attention. Solid waste mainly comprises food, paper, and plastic and improper handling of such waste may lead to poor

environmental human health issues. The city understands that improper dumping of urban waste could also affect the value of properties, particularly solid food waste that creates conditions necessary for the growth of microbial pathogens. In KSA, the major practice is the collection of waste from individual and community bins, which end in dumpsites or landfills. Recycling, reuse, and energy recovery practices are at an early stage. To address the solid waste menace, the government has increased its efforts on MSW through an increased budget for municipal services. The Saudi government focuses on practices such as anaerobic digestion, especially for food wastes. It has also invested in electronic waste treatment, licensing process, biological methods, as well as community projects on waste management.

7.5.1 Anaerobic Digestion

The Saudi government acknowledges that anaerobic digestion is one of the best practices for food waste recycling, given that KSA is known for high food wastes during Hajj and other holidays such as Ramadan. The word anaerobic means lack of oxygen. In other words, the process involves the breakdown of organic waste, such as wastewater bio solids and food wastes in Jeddah. The process helps in the production of biogas in a reactor. The reactors or sealed vessels contain microbial communities that break down the waste to produce resultant biogas and digestate. Jeddah city's anaerobic digestion of food waste leads to food waste sustainability, as it reduces reliance on landfills. It is an alternative to renewable energy and helps in the reduction of greenhouse gas emissions, which pollutes the environment. The kingdom has a high food waste accumulation, which makes anaerobic digestion a suitable waste management practice.³⁷⁶ The process promotes the generation of renewable energy, given that biogas is a renewable energy

³⁷⁶ Mu'azu, Nuhu Dalhat, Nawaf I. Blaisi, Ammar A. Naji, Isam Mohammed Abdel-Magid, and Ali AlQahtany. "Food waste management current practices and sustainable future approaches: a Saudi Arabian perspectives." *Journal of Material Cycles and Waste Management* 21, no. 3 (2019): 678-690

source. Biogas contains methane (CH₄) and carbon dioxide (CO₂). Biogas helps in fuel internal combustion engines that lead to electricity and heat production.³⁷⁷ Biogas also goes through compression to act as natural gas for cooking and as vehicle fuel. It eliminates the use of non-biodegradable fuel sources, thus helping in environmental conservation. Today, Jeddah city has poor waste management practices due to the use of landfills that damages the environment due to the attraction of flies and vermin, which are dangerous to human health. Landfills are unsustainable waste management practices, but the introduction of anaerobic digestion gives room for more sustainable waste management options in Jeddah. It will divert resources as well as use less space than landfills. Anaerobic digestion involves the breakdown of insoluble organic matter into fatty acids, simple sugars, and amino acids. The sugars and acids are then further broken down into alcohols and volatile fatty acids before their conversion into acetic acid, CO₂, and hydrogen. The final stage involves the conversion of methane and carbon dioxide from acetic and hydrogen using methanogenic bacteria. Unlike landfills, anaerobic digestion helps in on-site waste management, which leads to low to no transport cost as opposed to the use of heavy trucks that end up destroying the city's transport infrastructure. The process helps reach even the local residents by encouraging household digesters that provide an essential source of cooking gas. Anaerobic digestion is suitable in Saudi Arabia due to high food wastes accumulation in the area because it prevents CO₂ from entering the atmosphere. Apart from methane, anaerobic digestion leads to digestate production, which comprises liquid and solid portions. Separation of such remains helps in the production of nutrient-rich fertilizer, which is essential in farming, making them a source of revenue.

³⁷⁷ Khan and Zakariya, "Biodegradable waste to biogas, 101-113

7.5.2 Electronic waste treatment methods

The Kingdom of Saudi Arabia produces about 3 million tons of electronic waste every year. Such waste has a negative environmental problem if not recycled or properly disposed of. Studies indicate that KSA is losing over SR 5 billion every year for failure to recycle e-waste. Advancement in technology such as smartphones and population increase has made solid waste to become a menace. A cell phone starts malfunctioning after about 2 to 3 years, which requires a user to change it to the latest version. It means that e-waste has become the fastest source of municipal solid waste. E-waste mainly comprises heterogeneous products and inappropriate management may have adverse effects on human health. To promote proper management of e-waste KSA suggests re-use, recycle, and recovery. The Kingdom has policies governing the treatment of e-waste in the region. The PME has also approached the private sector to encourage avoidance and prevention of producing high volumes of e-waste and to design equipment with less hazardous materials as well as increase the lifespan of their products. The policy also encourages the private sector to invest in recycling, metal reclamation ventures, as well as energy recovery. Restrictions on the import of electronics that fail to meet international standards are in place in KSA. The designated agencies enact legislations for the management of electronic wastes, while others collect and regulate their circulation before they become wastes. Jeddah has made feasibility studies on investment in electronic waste management as well as carrying out awareness campaigns to encourage e-waste recycling.

The city of Jeddah practices the recycling of electronic wastes, but their practices are manual and labor-intensive. During the recycling of e-waste, flames may also lead to air pollution, affecting the ecosystem. The informal sector in Jeddah is the one engaging in the recycling and reuse of e-waste. Therefore, to ensure the recycling of e-waste is high and done in

the right way, the local and central governments need to invest in recycling plants to help in zero e-waste elimination in the city. The challenge is that the kingdom lacks clear regulations on e-waste management but with increased awareness, the country is starting to realize the importance of e-waste recycling. Landfill disposal is another practice of treating e-waste in Jeddah. However, the lack of modern landfills has led to soil and groundwater contamination due to poor e-waste disposal. Another practice is the incineration of e-waste. It is a process of burning electronic wastes using high temperatures. Burning help destroy organic components of e-waste, reducing their concentrations. However, incineration must follow the correct and modern methods to reduce the effect of air pollution. In KSA, there are e-waste management centers where people sort-out and reuse e-waste. In order to improve the current management practices, there is a need for e-waste legislation. E-waste management is a source of employment for high skilled and unskilled city residents. Cities in KSA need to stop dumping e-waste into landfills and recycle as many landfills in the country are about to reach their maximum capacity. Additionally, the city of Jeddah needs to involve the private sector and increase public awareness for e-waste, which will help in the development of an integrated e-waste management system.

7.5.3 Compositing and Other Biological Practices

As earlier illustrated, KSA practices biology in waste management through the application of anaerobic digestion. The kingdom also utilizes compositing, which has many benefits such as reduction of solid waste volumes, waste stabilization, destruction of pathogens, and production of biogas for energy use.³⁷⁸ Compositing is an aerobic process, whereby degradable organic carbon in solid waste materials is converted into carbon dioxide. The process helps turn organic matter into useful products such as fertilizer, useful for soil amendment.

³⁷⁸ Khan and Zakariya, "Biodegradable waste to biogas, 101-113

Compositing remediates soil using hydrocarbons. The decomposition process requires open windows or total enclosures to avoid air pollution. It requires an environment where microorganisms in wastes can rapidly decompose. Most common composting plants in KSA utilize aerobic rather than anaerobic decomposition. In aerobic decomposition, microorganisms require free oxygen to degrade the waste. Unlike dumping into open dumpsites and landfills, compositing helps reduce waste odor and toxic fumes.

Pyrolysis

KSA produces about 15 million tons of waste per year, with Jeddah's waste more than 4.5 million tons, which is about 30% of all kingdom's waste. Plastic waste is on the rise and Jeddah can convert these tons of plastics into liquid fuel. In the city, various waste-to-energy techniques such as pyrolysis are gaining attention as an alternative way for plastic waste treatment. The process requires high temperatures in absence of oxygen, which forms vapors and char. Condensation of the vapors occurs, which forms the liquid fuel. The process is easy, takes about 3 to 4 hours, and has the capability of improvement through the addition of catalysts to reduce temperature and retention time. Char, on the other hand, is an un-burnt plastic, which remains in a reactor after the pyrolysis process. One can utilize it as an adsorbent in wastewater treatment whereby one can increase its adsorption value through thermal activation. The process also leads to the production of gases such as methane, which have the potential of being used as an alternative to natural gas.

7.5.5 Community Projects on Waste

Food waste has become a menace in KSA. To address this problem, community projects have emerged, intending to increase awareness on the dangers of such food waste. The projects are evident even at the restaurant level, which aims at preventing increased food wastes from left

offers. Through "Do not waste food" community campaigns, the society is trying to change a culture, which believes in fresh food, and respects strict hygiene. Education programs such as It'aam Food Charitable Society help in increasing awareness of the importance of food conservation. Charitable programs are evident in KSA. Even though the country experiences surplus food levels, social inequality and food insecurity are evident. To reduce such waste, community projects aim at food redistribution and fit the Islamic tradition of charity. There are also food bank branches even in Jeddah where an organization such as It'aam Food Society collects food and distributes it among city families. Rich families are even putting up big refrigerators in front of their houses as well as invites people to donate food to help the needy.

People of Jeddah love their city as they enjoy exploring the sea, breathing fresh air. However, solid waste is destroying their clean air as people throw wastes from their cars, making solid wastes to fill the roadsides and the sea. Some people are unhappy with the polluted environment around them, which has made some engage in community projects to try to save their surroundings. For example, family projects on recycling are on the rise as families start to understand that their levels of waste production are unsustainable. Family waste collection centers such as Mawakeb Alajer collect recyclable plastics. They have a waste management system, which sorts donated plastics and takes the recyclable items to factories. Other initiatives such as Naqaa Sustainability Solutions have given the people of Jeddah new ways of managing their solid wastes. The initiative is a social enterprise that has engaged in green initiatives that have helped in the promotion of environmental awareness in Jeddah. These community projects aim at building sustainable waste management programs through the introduction of high-quality recycled products. Naqaa, for example, raises awareness among the general public, pushing for a strong and healthy society. Naqaa also contacts businesses asking them to develop sustainable

plans as well as going to parks and around the city to teach the community on the importance of keeping neighborhoods clean. Other groups such as Jeddah Ploggers and Team Up to Clean Up go around the city of Jeddah with volunteers to clean up the city streets. They collect and sort out the trash as well as create awareness on waste management practices.

8 RECOMMENDATIONS TO IMPROVE CURRENT STATE OF SOLID WASTE MANAGEMENT PRACTICES IN JEDDAH, SAUDI ARABIA

8.1 Introduction

Local authorities and central government have a big challenge in ensuring zero waste in Jeddah. The city is producing over 4 million tons of waste every year, which the majority ends up in landfills and dumpsites. Jeddah has to improve on its recycling, reuse, and energy recovery practices because they are at an early stage. The awareness has started to increase, increase the attention of sustainable waste management but the city has a very long way to go. According to current statistics, recycling is at a very rate of about 10% and is mainly practiced by the informal sector. Solid waste scavengers have increased the level of reuse and recycling of metals, glasses, plastics, and paper with very limited support from the local and central government and under unclear regulations.³⁷⁹ The only way KSA cities such as Jeddah can resolve their waste management problems, they need to create a healthy general environment and target the waste sector through clear and tough legislations, technology, and supporting local communities. The city needs to enforce national environmental standards as well as nee municipal codes on solid waste management.³⁸⁰ The city utilizes open landfills, which are rarely maintained or improved. To improve in this area, the city needs to engage in the modernization of landfills and well encouraging coordination among various stakeholders such as the private sector. There is also a

³⁷⁹ Ai, Ning. "Challenges of sustainable urban planning.

³⁸⁰ Anisurrahman, Mohammad, and Habib M. Alshuwaikhat. "Determining sustainability assessment indicators for the Holy City of Makkah, Saudi Arabia." *Arabian Journal for Science and Engineering* 44, no. 5 (2019): 5165-5178

need for KSA to create environmental awareness to the public, as well as encouraging scientific approaches towards solid waste management.

8.2 Enforcement of national environmental standards

The Kingdom of Saudi Arabia needs to encourage the enforcement of national environmental standards, which will help create awareness across the country. National standards are essential because they help protect the health and safety of humans and the environment. The Kingdom fails to enforce available laws such as limit emissions of pollutants or dumping of waste into water bodies. The kingdom's general regulations on the environment encourage balanced environmental activities by taking care of the environment through the protection and conservation of natural resources.³⁸¹ National standards also call for the promotion of awareness in society with an aim of sustainable development. Without such national laws, businesses and individual citizens across Saudi Arabia may engage in whatever waste disposal or treatment convenient or cost-effective even if the practice hurts the environment. Enforcement of national standards on the environment is essential because stricter law enforcement tends to increase innovative ideas on how to operate using environmentally friendly practices. People tend to come up with technologies that will help them avoid MEPA fines or the cancellation of licenses. Law enforcement increases the demand for sustainable technology because companies and individuals have to follow strict environmental regulations, which makes researchers, investors, and clean energy entrepreneurs focus on clean technologies

³⁸¹ Al-Hasawi, Hamad. "Investigation of municipal solid waste management in GCC states." (1999).

such as green energy technologies.³⁸² In other words, for KSA and Jeddah to see innovation in the waste management sector, the government needs to enforce strict national laws, including jail time and heavy fines, to see new technologies on waste treatment for them to avoid punishments. Today, people complain that sustainable technologies are unavailable but enforcement of national standards on these technologies will make them readily available and more accessible.

Enforcement of national standards also helps eliminate cost uncertainties. Business evaluates environmental laws in a negative light, which requires constant enforcement to make them adapt their business practice.³⁸³ Therefore, a business may require government enforcement to accommodate any new law such as banning landfills. Failure to implement these environmental laws leads to death, illness, and habitat destruction, which is mainly hard to quantify in monetary terms. Enforcing such laws may even prove cost-effective as businesses may benefit from reducing waste and energy costs despite high initial costs. National environmental standards help clear confusion across all cities. To ensure that a national standard benefits every citizen, enforcement is very essential. A national law that imposes regulations without considering their impact on local communities may end up failing. Therefore, to understand an impact of a national environmental standard, the central government has to enforce it to understand its results. Enforcement encourages community participation in the management of the environment, ensuring compliance with national standards. Having a national law on the environment in KSA is not enough to eliminate wastes in all its cities. Effective administration of these national standards is very important. Enforcement of these laws requires cooperation between the local municipalities and the central government of Saudi Arabia.

³⁸² Al-Hasawi, Hamad. "Investigation of municipal solid waste management in GCC states." (1999).

³⁸³ Al-Hasawi, Hamad. "Investigation of municipal solid waste management in GCC states." (1999).

National environmental law has a direct relationship with international environmental standards. National laws help in the implementation of environmental agreements. Countries such as Saudi Arabia are in different international agreements, which the state has promised to enforce certain environmental laws within their national legal systems. State nations are the drivers for the implementation of international standards because international laws have to collaborate with national standards for them to become effective. Agenda 21 of the United Nations Conference on Environment and Development (UNCED) encourages enforcement of national laws because it is as important as making laws.³⁸⁴ The Agenda requires governments to make their environmental laws more effective as well as establish judicial, administrative procedures, and integrated strategies that ensure maximum compliance with the stipulated national laws and regulations.

KSA is experiencing a gap between commitments of national environmental standards and enforcement. The central government fails to pay adequate attention to inspection and monitoring national laws put in place to protect the environment. Such laxities have led to a lack of violation deterrence, giving a rise to a culture of disobedience, thus weakening the benefits of national environmental laws. Administrative enforcement does not only mean punishment, sanctions/license cancellation, or suspension. It also includes rewards or incentives. Currently, there are no incentives for engaging in recycling or green energy waste management laws. Therefore, for KSA to enforce national standards on waste management, they need to introduce incentives to companies and individuals who adhere to national environmental standards. Conclusively, for KSA to deter violation of environmental standards, it has to engage in national enforcement. It has to ensure enforcement of fines without discrimination or withdrawal of

³⁸⁴ Montagu, Caroline. *Civil society in Saudi Arabia*, 2015

permits, as well as the closure of polluting companies to promote a culture of obedience and innovation towards national conservation.

8.3 New municipal codes on solid waste management

Currently, the municipal laws on solid waste management in Jeddah are weak and hardly enforced. Illegal tipping and dumping have become widespread. Compliance with waste regulations is poor and in some cases fraudulent. The results are a continued accumulation of wastes on the roadsides and overflowing landfills. The poor performance necessitates the local municipalities such as Jeddah municipality to adopt new codes that ensure that the holder of waste takes all necessary steps to make sure that waste has a description that permits its safe handling and management. For example, the city needs to come up with new codes for solid waste classification. Such codes will help in determining the type of business that produced a waste, point of generation, and description of the waste. Such classification will make it easier for the city of Jeddah to come up with plans on how to dispose of each type of waste.

In terms of licensing or permits, the municipal council needs to ensure that all people disposing of solid waste in the city have a city permit. Additionally, to reduce waste management chaos, the council needs to ensure that not all people collect recyclable materials from residential premises across the city. Those allowed to do so must have a residential recycling license issued by the city. The residential recycling license will be a newly added permit in addition to any business permit required by the current municipal code.³⁸⁵The city also needs to enforce licenses only issued by its municipal to avoid conflicts between the local and central government. New

³⁸⁵ Al-Hasawi, Hamad. "Investigation of municipal solid waste management in GCC states." (1999).

municipal codes on the delivery fee of solid waste are essential. Jeddah needs to ensure that it has a well-established delivery fee plan for operators transferring solid waste to transfer stations. The code should establish fees per delivery of every ton of solid waste to transfer stations as well as the appropriate transfer time, such as after normal working hours. The rules need to ensure that one cannot transfer or delegate an existing solid waste collection permit without the city's approval. Jeddah city also needs new rules that ban plastic bags to help limit retailers from providing single-use bags and non-recyclable paper bags. To put pressure on city businesses, the City of Jeddah needs new codes that govern waste disposal by private businesses such as restaurants. In Jeddah, food waste is common, as residents believe in eating fresh food while leftovers go to landfills or open dumpsites.³⁸⁶ To prevent such behavior, new rules should ensure that those producing more than 10-gallon containers of garbage to dispose of their waste through private sanitation service. This means that the municipality needs to come up with new laws that encourage local authorities' collaboration with the private sector.

The municipalities need to come up with new rules that encourage recycling, reuse, and energy recovery. The current municipality code recommends landfill dumping. To change such a culture and protect the city environment, Jeddah municipality needs to come up with new rules that encourage sorting and reuse at the household level. The new rules need to enforce the placement of two different colored garbage bins to ensure that organic and inorganic waste does not mix. Such laws will help the city change its solid waste disposal behavior and adopt environmentally friendly practices. In other terms, the new rules need to encourage source segregation of solid waste to help in converting waste into wealth through reuse, recovery, and

³⁸⁶ Medabesh, Ali, and Syed Md Faisal Ali Khan. "Sustainability Management among Enterprises in United Kingdom and Saudi Arabia." *Academy of Strategic Management Journal* 19, no. 2 (2020): 1-13.

recycling. The waste generators including commercial and residential premises must segregate biodegradables, solid waste, and hazardous wastes before handing them over to designated municipal collectors. Such laws will ensure that restaurants and hotels segregate biodegradable waste as well as set up a system that ensures the food waste is utilized for composting or anaerobic digestion. The new municipal codes should require manufacturers or any brand owners, especially those engaging manufacturers of sanitary napkins have a responsibility of creating awareness regarding proper disposal of their wastes. The laws need to ensure that a waste generator provides a wrapper for disposal of sanitary products along with the packet of their sanitary products. Also, new codes are necessary to regulate non-biodegradable products by requiring all brand owners to have a system in place that collects back the packing products or waste such as plastic bottles or glasses. The laws should also ensure that companies dealing with industrial waste earmark 5% of their total plot area for a recovery and recycling facility. The new rules need also to promote the market for compost and recycled materials in the City of Jeddah.³⁸⁷ Finally, the new municipal codes need to encourage incentives for companies and business engaging in waste treatment practice such as reduction of permit fee or reduction in operational taxes, to encourage city residents to engage in clean waste disposal practices, which will help protect the environment as well as the health of the City residents.

8.4 Enforcement of municipal codes on solid waste management

The new municipal codes establish how residential, commercial, and local habitats of the city have to conduct themselves when it comes to the collection and disposal of solid wastes. The

³⁸⁷ Fisher, Linda R. "Multi-market impacts of market-based recycling initiatives." *Journal of the Air & Waste Management Association* 49, no. 9 (1999): 1089-1095.

code gives the residents standards that help to guide the best solid waste management practices. Enforcing these municipal codes is essential in protecting the integrity of the municipality as well as establishing fair and responsible waste management practices. Implementing or enforcing such codes involves allegation investigation, imposing sanctions, fines, and even arrests. One way of enforcing the new codes is by clearly explaining to city residents the best and accepted waste disposal practices. The municipal councils need to discuss the new codes with the city residents to help them understand sanctions or fines relating to every violation of new laws. It can do so by posting the new codes of waste management across the city to help serve as a constant reminder of a resident's obligation and repercussions that come with violation of waste management rules. The City of Jeddah needs to come up with an enforcement committee that will help reach all the city residents to explain the goal and investigate any violations. In other terms, the city needs to select the right enforcement authority and mechanism. It needs to weigh the pros and cons of using the present legislation enforcement authorities compared to the creation of new enforcement authorities and institutions. The enforcement agency needs to be neutral by being free of any connection to the waste management sector. The municipality needs to sufficiently train the enforcing agency to ensure effective legislation and commitment to success. The municipality also needs to fund the enforcement by making sure that all violators of waste management codes receive appropriate fines. They also need to accumulate revenues from issuing permits or licenses to help fund the enforcement practices. In addition, penalties need to ensure that they avoid enforcement difficulties. They have to be tailored in a manner that deters violations of the new codes but not excessive because doing so would undermine public support.

The procedure for license cancellation or suspension or imposing sanctions needs to be fair and transparent and need to be consistent with the existing national laws. The municipal

council needs to come up with tools for enforcement monitoring such as research and surveillance programs, level of public awareness on best waste management practices, reporting requirements, constant inspections, as well as assessment of fines for non-compliance with new waste management practices in Jeddah. The municipal council needs to understand that the best legislation is the one that enforces itself to the public through increased awareness, which empowers them to support the new legislation. The municipalities have to coordinate with the central government for smooth enforcement of the new rules. The coordination will also help local authorities receive enough funding to help them enforce the new waste management codes. Finally, enforcement does not mean punishment. The municipal code can also reward individuals and companies who apply the new codes on waste management. Doing so will attract more local residents into following the new codes, thus increasing their awareness.

8.5 Modernization of landfills

The City of Jeddah and KSA as a whole need to shift from the old waste disposal methods of dumping their solid waste such as putting waste in open dumpsites and landfills. As earlier illustrated, landfill dumping is the most common practice of MSW disposal within the City of Jeddah.³⁸⁸ The City needs to modernize its landfills in order to ensure the protection of public health and the environment. Modern landfills ensure a safe and efficient environment by protecting the groundwater, surface waste, land, and air, all leading to conservation of natural resources and health, which will lead to sustainability in solid waste management in Jeddah. Before, dumping the waste into these modern landfills, the city must start by engaging in waste reduction, reuse, recycling, and energy recovery before depositing the remaining waste into a

³⁸⁸ Radwan, Neyara, and Sajjad Ali Mangi. "Municipal solid waste management practices and opportunities in Saudi Arabia." *Engineering, Technology & Applied Science Research* 9, no. 4 (2019): 4516-4519

landfill. Modernization of landfills will ensure regulation, testing, and monitoring of the environment to ensure that they are environmentally safe. In other terms, modern landfills will ensure enforcement of national and municipal standards through increased inspection and testing. The landfills protect the groundwater because of their protective layers made of clay and plastic that cover the bottom of the landfills, preventing landfill liquids also known as leachate, from reaching the surface or groundwater. Instead, modern landfill leads to collection and treatment of leachate unlike in the old landfills where the leachate was left to pollute the environment, due to its bad odor, and contaminate the groundwater. Daily work of covering the landfill waste is encouraged to prevent unwanted parties from displacing the waste or wind from blowing away the litter.

A modern landfill comprises a bottom liner, cells, leachate collection system, storm water drainage, gas collection system, groundwater monitoring system, as well as a cover. The bottom liner prevents the buried waste from reaching the underlying natural soils as well as the groundwater. Municipal solid waste landfills must have clay and synthetic layer whereby the synthetic one comes from durable puncture-resistant plastic from high-density polythene. The cells help in compacting waste using heavy machinery. At the bottom of a modern landfill is a leachate collection system. Its design makes the bottom surface of the landfill slope to a low point also known as a sump. The slanting helps any waste from the solid waste to drain for collection and treatment. The system comprises perforated pipes, gravel packs, and a sand layer. After leachate removal, it then proceeds to a holding tank or pond. The modern landfill also requires daily coverage of waste using six inches of compacted soil or an alternative daily cover. Groundwater monitoring systems help verify the landfill performance. Modernization of landfills will help in replacing the old and current landfills in Jeddah, which included digging a hole in the

ground and filling it with solid waste. After reaching a certain level, the City engages in incineration, which leads to the production of toxic fumes, which poses risks to residents' health. The old landfills have also led to many environmental concerns necessitating a modern landfill in Jeddah. The old landfills have common characteristics such as being in unsafe and inappropriate locations, mainly in large and unused space without considering the surrounding environment. Modernization of landfills, on the other hand, encourages health considerations. The old landfills led to groundwater contamination due to a lack of protective layers. However, with modernization, the contamination will be outdated. Improved liners in the modern landfills act as a barrier between disposed of solid waste and the soil below. Modernizing the landfills in Jeddah will also help prevent the release of methane gas, which is a natural product of landfills. The gases trap and hold heat into the atmosphere referred to as the greenhouse effect. However, the modern landfill will ensure the reduction of greenhouse gases released in Jeddah. Modernization of landfills will also ensure the reuse of space once a landfill closes unlike in the past whereby open landfills prevented vegetation growth due to soil contamination.

In other terms, the modernization of landfills will ensure that Jeddah is safe from gas emissions and litter. The modern landfill will also help Jeddah City to develop renewable energy programs. In other terms, Jeddah will engage in innovative ways of waste management, which will be a source of employment. The modernization will also promote a green energy system, leading to the conversion of landfill gas into electricity. Jeddah City, Saudi Arabia, has been suffering for decades from the solid waste placed in Wadi Nakhil, to the east of the city. The landfill facility is about 80% full and did not utilize any modern technology before its opening in 1982. The city has been depositing its solid waste into the municipal landfill for over 30 years and to make the matters worse, the landfill is so close to the city, which poses risks to the health

of city residents as well as endangering the ecology. The only way the city can escape such waste challenges is by investing in modern landfills.³⁸⁹ The modern landfill will change the past waste management behavior in the city where little attention applied when choosing the location of a landfill. Modern landfill requires locations that protect human health and environment. One cannot construct a modern landfill in floodplains given that Jeddah suffers from constant flooding. Municipalities cannot build landfills on wetlands or fault areas. Openly burning of wastes in Jeddah will be outdated, thus eliminating air pollution and health hazards. The covering of landfills after reaching their predetermined height as evident in KSA today is unsustainable. Sustainability advocates for the conservation of natural resources such as soil but the old designs degraded and contaminated the soil, preventing any vegetation from growing. The methane gas escaping from the final cover has the capability of moving offsite into the building, which means homes in Jeddah faces potential explosion risks. However, in contrast, the modern landfill will ensure Jeddah's health and environment is safe and habitable because modernization will help the city gain control of their waste, preventing water and air emissions from MSW using protective membrane layers or liner systems.

8.6 Coordination among various stakeholders

Jeddah City needs to encourage coordination among all stakeholders in waste management. The city has to do so bearing in mind that poor waste collection and disposal in many cities across the world are suffering from diseases and low economic performance due to lost workdays, treatment costs, and paying labor to clean up and unblock drainage systems, as evident in Jeddah. Inadequate waste treatment may result from a lack of coordination and

³⁸⁹ Ai, Ning. "Challenges of sustainable urban planning.

cooperation among all the stakeholders including local and central government. Sustainable waste management requires an interdisciplinary relationship to help solve the problem of urban solid waste.³⁹⁰ Therefore, for Jeddah to attain zero waste in line with Vision 2030, the involvement and participation of all stakeholders such as waste generators, waste processors, informal and formal agencies, government, and non-governmental organizations, as well as financial institutions are very crucial. Interaction by all actors in the waste system including the waste generators such as households can help address a large part of waste management problems. There is a need for national and local governments to involve research institutions, the private sector, NGOs, the public, and the academic in their waste management plan while implementing a sustainable waste management system. The local authorities cannot eliminate waste across Jeddah without the help of the central government, the public, and other institutions such as banks. The local authorities may require mobilizing the community towards waste treatment activities such as sorting. It cannot do all the work on its own, as it requires public participation and financial resources to come up with an adequate waste management system.

Stakeholder involvement relates to activities such as generation, reduction at the source, collection, treatment, and disposal of solid waste. The public is a major stakeholder in waste management because increased awareness on issues such as sorting, segregation at the source, and recycling means reduced MSW. Public participation is very essential because the public or people living in both commercial and residential buildings in Jeddah form the biggest stakeholders when it comes to waste management. Their stakeholder is bigger because they are the waste generators. This has made the rate of waste generation in KSA major cities such as Jeddah increase because people's population is rising every day, which translates to high solid

³⁹⁰ Montagu, Caroline. *Civil society in Saudi Arabia*, 2015

waste generation. The public also serves as the largest waste service client from the local authority as well as receivers of information on waste reduction practices. To mobilize an agenda on waste management in the city, will require public participation. Municipal solid waste management agencies collect waste from bins placed outside residential and commercial buildings. In other words, they determine the working of waste pickers, private companies, and local authorities. Jeddah City needs to involve the public or the household in proper ways of handling solid waste. The city needs to encourage the public to practice separation of waste at the source and the city should support them by giving them more than one garbage bin. Additionally, public participation will lead to smooth waste management practice, as the local authority will have the capability to set a time and place for waste collection. The authorities have to involve the public to promote a culture of obedience such as disposal of solid waste into official locations instead of throwing them into the city's roadsides. Public participation is necessary in order to ensure sensitization and community projects as people will learn the importance of keeping their environment clean. To ensure total participation, the city also needs to involve religious leaders to help stimulate the desire for reuse, recovery, and recycling. Religious leaders will help motivate people to participate in community clean-ups and preaching the importance of keeping the environment clean, during their sermons. Schoolteachers are also crucial stakeholders in supporting cleanliness campaigns. Schools in Jeddah need to start teaching the children the importance of recycling or reusing solid waste. Spreading the message in schools will help reach more city residents including those unable to attend school. Involving the public in their waste management plans will increase awareness on modern waste treatment methods, keeping the city clean of solid waste. The city needs to invest in media campaigns and NGOs. Neighborhood committees will help give people responsibilities in waste management.

Jeddah City can encourage such participation through incentives such as giving rewards to cleaner households.

Jeddah City's authority also needs to encourage private sector participation in the city's solid waste management practices. The private sector can help the local municipality in the waste collection including transport, processing, and solid waste disposal. To encourage private sector participation, the city can create competitive tenders, which will help in cleaning the city. The local authority in Jeddah may also encourage participation through incentives such as tax holidays for companies engaging in anaerobic digestion, composting, or those recovering energy from waste. It can also encourage low rates in acquiring land for setting up a recycling plant or modern landfill. Local authorities can also offer loans to private agencies focused on solid waste elimination in the City of Jeddah. It means that for more private sectors to engage in waste management practice, Jeddah municipality and central government need to come up with fair SWM tax to reduce the costs of waste management. People in high-income areas could participate in waste management through a minimum tax while those in low-income areas receiving token charges to encourage participation in urban waste management. The City's waste management agencies also require support from policy and financial institutions such as law institutions and banks. Banks are essential in urban planning because they can provide the municipality with money to maintain and build new waste treatment infrastructure.³⁹¹ Legal institutions such as courts are essential stakeholders in waste management because they help in the enforcement of proposed regulations on SWM including fines and revocation of licenses or imprisonment in case of environmental pollution activity. Urban planners are also essential stakeholders in waste management as they help in integrating the environment in urban projects.

³⁹¹ Lippitt, Paul, et al, "Planning for waste minimisation , 65-75

They design appropriate landfill sites as well as the city's drainage system, which are essential infrastructure in urban waste management.

In summary, involving the public as a stakeholder in Jeddah will help waste reduction at the source as well as source segregation. The city will also find it easy to locate sites for modern landfills with public cooperation as well as smoothly run these landfills because the same public will be paying for waste management. The local authorities will help in the provision of infrastructure, staff, punishment of violators, and implementation of solid waste legislations, database maintenance, and informal sector involvement. The teachers will influence minds and instill a culture of waste reuse, recycle, and recovery while the NGOs help Jeddah create networks, integrating the waste management system.

8.7 Creation of environmental awareness to the public

For the City of Jeddah to become successful in managing its waste, it has to insist on public awareness and participation. Waste mainly results from human activities, which means that every person in Jeddah must have a clear understanding of waste management problems because, without such knowledge, any waste management plan could fail. Increased awareness will help to make the public more accountable for the amounts of waste and pollutants they produce. It will help the City of Jeddah promote a culture of producer responsibility, which will ensure that no one is lax on the number of waste people produce. Public education is essential in any waste management plan. In fact, the amount of waste reuse or recycle depends on the pro-environmental behavior of the surrounding population. According to the theory of planned behavior by Ajzen and Fishbein, people's attitudes determine their behavior. It means that if Jeddah encourages a cleaner environment through proper reuse and recycling of solid waste, it

would change people's attitude towards open dumpsites and landfills, encouraging proper waste management behavior. Jeddah has to increase its level of environmental awareness by educating its residents on the importance of reuse, recovery, and recycle. Such awareness will motivate them towards making efforts that solve the current waste management crisis facing the city. Creating environmental awareness will help the residents evoke the necessity and responsibility to respect, protect, as well as to preserve the city's natural resources. Awareness will help the residents see that the environment is delicate and for it to survive or be sustainable, it requires the effort of the young and the old. To do so, the cities have to invest in media campaigns, as earlier indicated, and encourage inspirational seminars across the city, and support environmental learning in schools.

The city can invest in posters and adverts to encourage Jeddah residents to sort their waste, reuse, or recycle solid waste materials such as plastics and metals. It can also encourage people to utilize glass water bottles instead of plastic ones because these plastics have become a menace to water bodies such as the Red Sea. Creating environmental awareness means that the city will be informing its residents of the dangers that result if they continue dumping the solid wastes into open landfills and dumpsites. Investing in environmental awareness in Jeddah will help promote environmental health. The city should insist on the importance of recycling and other green practices. The culture of environmental conservation should start at an early age especially in schools because doing so will help children grow with high respect for nature. Creating awareness of best waste management practices will make it easy for people to adopt new and better technologies for waste management. Increased awareness in Jeddah will also promote a healthy lifestyle such as proper storage of waste. The creation of awareness to the public will also help the city residents develop the confidence to investigate and solve waste

management problems facing their city. Awareness promotes interpretation, investigation, and problem-solving. The public cannot understand the problem that is facing the city or how their activities contribute to the waste management menace without educating them. The city has to spell out to them clearly that lack of source segregation is making it hard for the city to engage in recycling of city solid waste or keeping their environment clean. Awareness also involves giving solutions to the current problem. It means that Jeddah has to educate its residents on the best methods of handling solid waste such as sorting and reuse. However, if the city does not invest in creating awareness, very few people will engage in waste segregation of reuse.

Awareness creation will lead to creativity and innovation in the waste management sector. The city residents will expect results from their waste management practices. Increased awareness will translate to a positive environmental attitude, which will enhance creativity. Environmental awareness will either educate society about the negative effects of pollution by toxic gases or smells resulting from poor waste disposal. To ensure zero pollution, the public will have to come up with new ways that ensure zero gas emission, which will lead to new waste management technologies. The awareness will not only make the public respond and save but will also create a new culture in businesses. The awareness will help manufacturers and consumers see their responsibility in ensuring a clean environment. The knowledge of the environment will make them demand more from their suppliers by asking them to reduce the amount of packaging or offer environmentally sound disposal methods at the end of their serviceable life. It will make a business calculate their benefits and costs of not engaging in recycling or reuse of products. To increase awareness on waste reuse, recovery, and recycling, the City of Jeddah has to engage in effective communications when dealing with all the stakeholders. The citizens have to be aware of their requirements and responsibilities in waste

management. In other words, citizens will engage in waste sorting and recycling if they are aware of the associated environmental benefits. As earlier indicated, for Jeddah to improve attitudes towards waste management practices such as reuse or recycling, the city has to integrate waste management into the school syllabus for children to understand the causes and impacts of poor waste disposal. Local municipalities need to send representatives to schools as well as inviting schoolchildren to recycle plant tours and community cleanup activities to instill a culture of reuse and recovery. Awareness-raising practice will encourage city residents to avoid the unnecessary generation of waste. Such positive influences of environmental awareness will lead to improved waste disposal and collection practices.³⁹² The awareness campaigns need to be consistent and clear, with well-stipulated goals and objectives. The city also needs to understand its audiences to correctly design the campaign messages. These awareness campaigns will help city residents overcome barriers to effective solid waste management such as lack of knowledge on proper knowledge on waste segregation and poor attitude and perception towards sorting and reuse of waste. The city needs to engage all the stakeholders in the delivery of awareness messages including NGOs, media, and professionals. In conclusion, the City of Jeddah must engage in environmental awareness campaigns to improve the methods of waste management as well as the health of its residents.

8.8 Scientific approaches to solid waste management

The City of Jeddah needs to improve its current scientific approaches to solid waste management. The city dwellers always have to deal with waste collectors as they collect and deposit the day's waste to collection trucks. What many do not know is that the waste ends up in

³⁹² Ejaz, et al., "Environmental impacts of improper solid waste management, 379-387

landfills, huge acres of land specified for waste disposal. The current landfills in Jeddah pose a major threat due to their unscientific design. Today's landfills emit methane gas from the waste accumulation and burning. Methane is a leading cause of fires at landfills, causing severe air pollution. These landfills are also health hazards as they store virus and bacteria, which causes heart and lung diseases. It is high time for Jeddah City to implement scientific landfills to encourage sustainability in the waste management sector. The landfill utilizes simple scientific technology and scientific landfill encourages control over gas and leachate. It also keeps away rodents and other vectors such as flies. Currently, the Wadi Nakhil landfill in Jeddah is nearing its full capacity. It produces poisonous gases, but a scientific landfill will help in waste treatment and urban waste management. A scientific landfill utilizes scientific design during its construction. Such designs protect the soil from contamination as scientific landfills arrest any waste seepage or leakage. Science also helps in degassing the landfill by reducing the rate of gas generation. Today, much of the waste generated in Jeddah remains untouched. A big percentage of this waste is food waste across all KSA cities. Most of the foods in KSA go to waste, as people believe in eating fresh products. Food waste has negative environmental effects as they pollute through bad smell and giving room for pathogens to multiply. However, instead of Jeddah residents endangering their environment and public health, they can increase their activities on Composting in order to reuse the food waste as soil nutrients. Food, an organic matter, can easily decompose. It the leading contributor to landfills but this trend can stop if the city residents convert it into compost. Today, the city disposes of the food unscientifically by depositing it into landfills. Putting the food waste into landfills leads to the destruction of healthy nutrients by toxic chemicals seeping from the solid waste, keeping people from benefiting. The city must raise awareness on scientific waste treatment methods such as compositing to

encourage the use of science in waste management. Jeddah should also practice biological reprocessing when dealing with waste management. This scientific method is suitable for solid wastes such as paper and plants. The organic matter, through biological decomposition using modified cellulose, helps in the improvement of physical properties of waste, such as paper, including fitness and strength compared to the conventional process. The biological process also leads to the production of gases that may help in the production of heat and electricity

The City of Jeddah also has an opportunity of converting waste to energy using waste valorization. The scientific process involves the conversion of waste materials into more applicable products such as chemicals and fuels. The process assumes that the solid waste contains an untapped polymeric substance that can be converted to energy or into chemical forms. The concept is suitable for both synthetic waste and bio waste.³⁹³ The world is facing increased depletion of natural resources, which makes waste valorization a much-needed technology for sustainable waste management practices. The process helps in the production of high-value chemicals such as ethanol and nano-bio plastics. The process also helps in the removal of waste odors, environmental pollution, as well as reduction of waste volumes. The city should also invest in thermal waste to energy (WtE) plants to generate electricity and heat.³⁹⁴ Wastes have a biogenic component that helps in the production of renewable energy globally. There is a rise in attention towards green cities and Jeddah can walk towards being green by investing in renewable energy. Thermal WtE plants help in the reduction of greenhouse gas emissions by diverting solid waste from open burning and landfills. Additionally, land

³⁹³ Sadeq, "Waste-to-energy and recycling value, 569-579.

³⁹⁴ Sadeq, Y., A. S. Nizami, S. A. Batool, M. N. Chaudary, O. K. M. Ouda, Z-u-Z. Asam, K. Habib, M. Rehan, and A. Demirbas. "Waste-to-energy and recycling value for developing integrated solid waste management plan in Lahore." *Energy Sources, Part B: Economics, Planning, and Policy* 11, no. 7 (2016): 569-579

constraints are an issue in Jeddah, which requires scientific methods that reduce waste volume and mass. Thermal plants will improve the health and environmental conditions in Jeddah. The city can also convert waste into energy using thermochemical conversion technologies. Thermo-conversion technology reduces dangers that come with open combustion. The City of Jeddah can also engage in plasma gasification. It is a scientific method of waste treatment that utilizes high ionized or electrically charged gases known as plasma through a vessel that helps convert carbon-based materials into fuel. New scientific technology helps in the treatment of hazardous solid wastes by converting the incinerator ash into a non-hazardous product. The utilization of high temperatures in the gasification process prevents any formation of toxins compounds, which makes the process ecologically clean and environmentally friendly. The high rates of population increase have overwhelmed the traditional and unscientific methods of waste management. Landfills and dumpsites are no longer viable means of waste treatment. It requires people to utilize science to come up with new inventions in waste management.

9 CONCLUSION

From the research, it is clear that KSA, including its cities such as Jeddah, is facing a high rise in population and urbanization. Such rises have led to the accumulation of solid wastes, mainly waste from the streets, demolition waste, as well as household wastes. For example, food waste in urban areas is on the rise as people have changed their lifestyles and the market system encourages food consumerism. However, these manufacturers have little concern about where their packing materials end up. In other words, laxity among waste generators and regulators is vivid in Saudi Arabia and the City of Jeddah to be specific. The current laws are inadequate because as illustrated, there are no measures controlling manufacturers regarding their level of waste generation. Inadequate laws are guiding the type of packing and appropriate packing such as biodegradable bags. Plastic bags and bottles continue to wreak havoc across all cities in Saudi Arabia because many lack sustainable waste management systems, including Jeddah. The local authorities are confronting inadequate finances, regulations, and limited support from the national government. With confusion, inadequate tools, and lack of motivation, enforcement of laws in the waste management sector has been poor in Jeddah, Saudi Arabia. The central government makes centralized decisions, which end up being infamous in the kingdom. KSA cities such as Jeddah are facing an urbanization problem because there are no strong laws to protect consumerism in these cities. Every day, people of Jeddah are consuming products packed in cans, plastics, and other non-biodegradable materials. After they are finished, they dump the solid waste on the roadsides, along the streets, and into surrounding water bodies and drainages. The littering leads to environmental pollution, endangering the health of all Jeddah residents. The risks arise because the city lacks proper methods of waste disposal. Most of these plastics, metals, and non-biodegradable materials end in open landfills and dumpsites. These old and open

landfills in Jeddah are dangerous to people living near them and to workers dealing with solid wastes. Open landfills, as illustrated by the study produce toxic fumes and gases that pollute the air. Residents living near breathe the polluted air, which ends up affecting their lungs and other body organs. The toxic gases from the landfills such as methane have led to an increase in diseases such as cancer and asthma. Therefore, due to poor waste management in the city of Jeddah, residents are left to spend their money on treatments or health care because there are inadequate laws and enforcement of present regulations. The informal sectors such as Jeddah's waste scavengers also face risks due to these poisonous gases from the open landfills. As earlier illustrated, the informal sector contributes to 20% of total reuse and recycling activities in Saudi Arabia. It means that every day, there are laborers in these open landfills searching for recyclable materials such as paper and metals. What this informal sector fails to understand is that they risk their health by going to these landfills. They breathe the toxic fumes as they scavenge for municipal solid wastes, putting their body organs at risk of pathogenic microorganisms present in these solid wastes. The poor disposal of solid waste affects the economy of the households, as they have to divert money to health activities instead of investing, which means disposal of wastes into landfills is economically unsustainable. Its unsustainability is also evident in water and soil pollution. Sustainability discourages interference with natural resources such as water or soil. However, the unsanitary landfills in Jeddah do exactly that because wastewater seepage into the soil affects its nutrients, preventing plant growth. Wastewater seepage arises because the present landfills and dumpsites lack a lining system encouraged by modern landfills. The lack of lining enables wastewater from the municipal solid waste to contaminate the soil as well as the groundwater.

The current waste disposal practices in Jeddah are unsustainable. The city produces more than 5000 tons of solid waste every day. The city relies on a collection of waste from bins scattered across Jeddah's commercial and residential buildings. The worrying trend is that the bins are not even adequate to cater to all residents, which means many people in Jeddah end up dumping their solid waste into illegal dumpsites. The landfill facility in Buraiman is nearing its full capacity, which means new ways of waste disposal are necessary for the city. Additionally, each resident receives one garbage bin, which leads to the solution of solid waste with organic wastes such as food. The waste management system, therefore, does not support the separation of waste at the source. It is an indication that people in Jeddah do not value sorting of waste to promote reuse, recovery, and recycling. It illustrates people's poor attitude towards activities meant to conserve and protect the environment. It is also an indication that there is little to no awareness of the benefits of waste separation in Jeddah. There is little documentation of local programs supported by the local and municipal government to create awareness on the importance of solid waste reuse, recovery, and recycling. The local agencies also seem to have few experts on waste management because Jeddah has not experienced any waste management technology for several decades. Jeddah City's engagement in waste management practices such as recycling, reuse, or conversion of waste to energy is very low. The 10% of the produced waste goes to recycling activities, which means the remaining 90% goes to landfills and little on composting activities. KSA composting practice needs to have gained the necessary attention given that the country is leading the other world countries in food waste generation. Religious celebrations such as Ramadan and Hajj promote food wastes across also cities including Mecca. However, even with that much food waste, composting practice is low, which is a sustainable practice because instead of contaminating the soil like landfills, compost helps to enrich the soil,

supporting plant growth. Compositing can also be a source of employment in KSA, but the present policies fail to encourage innovation. Additionally, the current environmental standards and codes are inadequate when it comes to sustainable waste management. Those given the responsibilities also face inadequate budget, tools, and motivation to enforce waste management rules, which calls for reforms in ways Jeddah, KSA disposes of its solid waste as well as the way relevant administrative bodies enforce their solid waste regulations. To attain solid waste management sustainability, Jeddah City has to adopt modern waste treatment practices. One is the recycling of municipal solid wastes such as papers, metals, and plastics. The local and municipal governments can support such activities by coming up with regulations that insist on the separation of waste at the household level or the source. Sorting will allow the separation of recyclables and non-recyclable wastes, which will make it easier for municipalities to engage in recycling. The municipal waste agencies can also provide tax incentives such as exemption of tax on all recycled or reused products, which will motivate the private sector to join in the solid waste management system.³⁹⁵ Currently, private sector involvement in waste management activities such as recycling is limited due to inadequate government support.³⁹⁶ Therefore, new codes and increased enforcement of these new rules are essential to help increase recycling attention. Increased awareness across the city is crucial and the private sector such as media is important in such activities. NGOs will also help Jeddah change its resident's attitudes through increased campaigns and community-based projects. Jeddah city also needs to come up with regulations that discourage landfill dumping such as high landfill costs and encourage the reuse of reusable solid wastes. For example, new regulations can help in the promotion of reuse

³⁹⁵ Alhumoud, Jasem M. "Municipal solid waste recycling in the Gulf Co-operation Council states." *Resources, Conservation and Recycling* 45, no. 2 (2005): 142-158.

³⁹⁶ Gharaibeh, Emhaidy et al., 110

activities. The new law needs to encourage the use of glass bottles instead of plastic bottles. Glass bottles will encourage reuse as the law may encourage the return of bottles to a retailer once one completes the bottle's content. The government of Saudi Arabia needs to enforce a national plastic ban. Many world countries have banned the use of plastics and non-biodegradable bags, but Saudi Arabia is still lagging, as there is no national law banning the use of plastics. Glass bottles will encourage reuse and recycling activities across Saudi Arabia's cities. Another recommendation is increased composting activities. New codes need to encourage composting, which will help reduce the poor disposal of food items by hotels and restaurants, which have become a crisis in Jeddah. There are a lot of food leftovers across Saudi Arabia's hotels and the only way Jeddah can confront the menace is by coming up with regulations that encourage composting.

Jeddah also needs to come up with regulations or codes that encourage the modernization of landfills. The current landfills were built in the early 1980s using outdated technology.³⁹⁷ Modern landfills encourage covering of landfills and building of lining systems to prevent wastewater seepage. The current landfills have no lining layers or cover. They release methane and other greenhouse gases, which pollute the environment as well as putting public health at risk. Their lack of lining leads to soil and groundwater contamination, preventing vegetation growth near the landfills. Modern landfills have a lining system and a cover that ensures the sustainability of landfills because only a small amount if any of greenhouses has, can escape a modern landfill. The plastic and clay lining layers prevent contamination of natural resources. Therefore, new municipal codes need to dictate that all landfills in KSA be modernized. New municipal codes should equip the local authorities with the authority to modern current landfills

³⁹⁷ Gharaibeh, Emhaidy et al., "Evaluation of current municipal solid waste practice and management, 103-110

by encouraging autonomy in revenue collection, which will equip them with the necessary resources and tools to enforce the codes on landfill modernization. The city also needs to embrace other scientific methods of solid waste treatment such as plasma gasification, which will enable the city to convert its solid waste into energy. Finally, it is clear from the study that Jeddah, KSA requires new municipal codes to help deal with the current solid waste management crisis. The local authorities suffer from duplication of responsibilities, limited jurisdiction, low funding, inadequate tools, and unclear duties when it comes to implementing solid waste management plans. The national agencies have all the jurisdictions, which makes it hard for the local governments to enforce waste management regulations in a city like Jeddah. The local authorities have no way of sourcing their revenue as they depend on the national government on funding, which makes them suffer from inadequate financial resources. The City of Jeddah is suffering from solid waste generation because there is no national law banning the use of plastics as evident in many cities across the world. The City's waste institutions receive less funding and operate under unclear regulations. National institutions such as Aramco implement plans meant for local and regional institutions, which creates confusion, complexity, and confusion. Therefore, instead of Jeddah's authorities enforcing laws to serve and protect the public, they start competing with national institutions, leading to poor delivery of waste management services. New regulations need to remove complexities present in current regulations. The new laws need to be clear in defining each agency's duty, from the national to the local level. The clarity in regulations will help eliminate duplication in jurisdiction and responsibility, thus helping in conflict reduction. Conflict reduction will in return lead to increased cooperation between the private and public sectors, which will make it easier for institutions to enforce the proposed codes and regulations.