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Analysis of seawater pollution factors in the port of Aqaba/ Jordan : from a sustainability perspective: challenges and solutions

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ANALYSIS OF SEAWATER POLLUTION FACTORS IN THE PORT OF AQABA/ JORDAN

From a sustainability perspective: challenges and solutions

by

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The Hashemite Kingdom of Jordan

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Declaration

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

(Signature):.....

(Date): .....22 Sept 2020.....

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Abstract

Title of Dissertation: **Analysis of seawater pollution factors in the port of Aqaba/ Jordan from a sustainability perspective: challenges and solutions**

Degree: **Master of Science**

The dissertation is a study to analyze seawater pollution factors and identify the main sources of marine environment pollution. The various activities of seaports and ship navigation in territorial waters are among the most critical causes of seawater pollution. The methodology used in this research is qualitative and takes into account a literature review. The literature review on marine pollution, seawater pollution factors, sustainable development, and green ports will be addressed to determine the best indicators for measuring the sustainable environment in seaports. Accordingly, an analytical framework for seawater pollution factors in ports will be examined and some methods available to reduce this pollution. A case study of the port of Aqaba will be conducted using the analytical framework to find the gaps, filling these gaps with solutions and recommendations. The case study will consider documents, port website, personal experience, and interviews with port operation managers. Finally, the gaps will be filled with solutions and recommendations to minimize seawater pollution and integrate sustainability in the port of Aqaba.

The analytical framework clarifies the seawater pollution sources were divided into four main sections, in each section identifying a set of most crucial seawater pollution factors in the port of Aqaba, besides ways to improve that are commensurate with the capabilities of the port of Aqaba. After that, a gap analysis help finds weaknesses and their size in the port of Aqaba that leads to the impact of seawater pollution factors on the marine environment. Consequently, recommendations and solutions will be presented by the stakeholders and the author.

KEYWORDS: Pollution factors, Seawater pollution, Sustainability development, Green ports, Marine environment.

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List of Abbreviations

ACPOM	Aqaba Company for Ports Operation and Management
ASEZ	Aqaba Special Economic Zone
EMSA	European Maritime Safety Agency
IOPP	International Oil Pollution Prevention
JMC	Jordan Maritime Commission
MARPOL	International Convention for the Prevention of Pollution from Ships 1973
MEPC	Marine Environment Protection Committee
MoE	Ministry of Environment
MoT	Ministry of Transport in Jordan
PRF	Port Reception Facilities
SDGs	Sustainable Development Goals
SOLAS	International Convention for the Safety of Life at Sea 1974
STCW	The International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers
TCC	Technical Cooperation Committee
UN	United Nations
UNCLOS	United Nations Convention on the Law of the Sea 1982
WMU	World Maritime University

Chapter 1: Introduction

1.1 Background

What is water pollution? Water is one of the most significant natural resources that man has destroyed for his use. Although water covers 71% of the Earth, the percentage of useable water is quite less, and unfortunately, humans have not wasted a single chance to pollute it (SOS.NOAA, 2019). Water pollution introduces any kind of energy or substance into the marine environment by humans, direct or indirect, which leads to the possibility of damaging the marine environment and life, obstructing marine activities, and endangering the human being (UN, 1982).

In addition to shipping and port operations, the increase in industrialization is haphazardly affecting our environment and hence resulting in the depletion of natural resources. Industrialization is not only causing air and land pollution but also resulting in water pollution (Dowd, 2017). Coastal waters are profoundly affected by land pollution, followed by seawater pollution. Seawater gets polluted by the industrial waste that is thrown into the river and merges into the sea. 44% of seawater pollution constitutes of the waste that ends up in the sea through rivers or pipelines (SOS.NOAA, 2019).

Shipping, port operations, and land-based activities are not the sole sources of water pollution; acid rain also results in seawater pollution. The harmful and toxic gases that stay in the Earth's atmosphere come down in acid rain. Daily traffic and air conditioners release carbon dioxide and chlorofluorocarbons into the air, thus adding acid rain (Mike Carlowicz, 2008). Not only are human beings impacted, but marine life is also devastatingly affected by seawater pollution. Floating garbage, oil spills,

high levels of metal in the seawater, nuclear waste, and plastic waste, etc. are destroying marine life (Mahbub, S. M. Parvez Bin, 2011).

Plastic material is considered one of the most harmful marine pollutants, impacting the environment and marine life, especially since large quantities of it were manufactured in the last decades, and it is an essential part of most industries. Plastic material takes many centuries to dissolve in seawater, and it can also turn into small plastics that fish and marine life eat, which is transported to humans through the food chain (LI et al., 2016). The Gulf area, such as Aqaba Gulf, is close to the mainland and is mainly affected by seawater pollution. Coastal waters have been affected by an increase in human population and industry ventures. Land-based activities are adding to the pollution in seawater. Water pollution is associated with both demographic and industrialization growth.

- **Causes of water pollution**

It was determined that 20% of marine pollution comes from marine activities such as commercial and tourist shipping, the fishing profession, and various types of debris. The other 80% of marine pollution comes from land-based origins such as factories waste, agriculture activities, residential neighborhoods, and sewage systems (Owa, 2013). Mentioned below are some of the significant sources of water/seawater pollution (Denchak, 2018):

- High population and an increase in sewage waste.
- Oil and chemical spills on the sea.
- Industrialization and heavy metals that are directly thrown in the sea.
- Floods during monsoons that drive waste from land into the rivers and then in the seawater.
- Agricultural waste and chemicals such as pesticides.
- Toxic waste dumped into the sea (Singh, 2016).
- Mining, exploration, and drilling activities in seas and oceans.

- Pollution of groundwater, especially from burying dangerous waste, which eventually reaches the seas and oceans.
- Acid rain, which is formed from an increase in carbon dioxide in the atmosphere.
- **Port operations and shipping.**

➢ **Water pollutants**

Water pollutants are described as chemical, biological, or even a physical entity that harms marine life and those living organisms that rely on water (UN, 1982). However, most of the water pollutants are in the form of chemicals that either dissolve in water or stay there in saturated conditions (Potters, 2013). Moreover, biological factors such as harmful organisms and pathogens can affect human and animal health as well as the marine environment when they are introduced in water; they are also known as bio pollutants (Goel, 2006).

1.2 Problem statement

The problem statement of this research is that human activities are causing severe damage to the natural environment. The main area of this research is seawater pollution, which is caused by many reasons and is affecting human health, marine life, and the overall environment. An increase in urbanization is also affecting coastal areas. Human beings, without having a second thought, dump every kind of waste into coastal waters (Todd et al., 2019). Mentioned below are the three main reasons behind water or seawater pollution:

- Industrial waste.
- Agriculture waste.
- Domestic waste.
- Marine ports and shipping.

- **Industrial waste**

A significant part of seawater is adversely affected by industrial waste. The manufacturing industry, including sectors such as mining, power production, and food processing, is polluting water all over the world, whether it is for domestic use or seawater (Gaur et al., 2020). The most toxic substances are usually released by the oil refining and chemical industries. Heavy metals are also released in the water, which later on ends up in seawater, thus resulting in seawater pollution (Naser, 2013). Other industries also release toxic substances and should not be neglected despite being on a smaller scale.

- **Agriculture Waste**

Agriculture waste is the other reason for increased seawater pollution. The use of pesticides and nitrogen-based fertilizers has become a part of modern-day agricultural methods in which the concentration of nitrogen increases in the water. It has hazardous effects on human health and marine life. Even the groundwater gets highly polluted with the use of pesticides (Onwuka et al., 2019).

- **Domestic waste**

A growing human population has contributed to an increase in domestic waste. Untreated sewage water is directly dumped into rivers and coastal waters. Human waste is polluting both land and waters, but the land-based pollution often ends up in seawater. Nowadays, almost everything is available in plastic wraps, even plastics such as straws that are used a single time end up in the trash. Most people tend to throw their trash without separating the recyclable materials, which ends up destroying marine life. Cleaning products and shampoos also contain a large number of chemicals in them. These are not highly toxic, but they still play their part in polluting the ground and surface waters (Gambhir et al., 2012).

- **Marine ports and shipping**

Marine ports and shipping areas are at the center of marine pollution. Land-based pollution also adds to the pollution at marine ports. Domestic and shipping waste are thrown into the sea without proper treatment, and the marine environment is severely affected. Even cruise ships release pollutants. For example, greywater pollution results from the sinks and laundry water dumped into the sea. Greywater mostly contains chemicals that are present in laundry detergents (Copeland, 2008).

Seawater pollution in ports occurs because of the operational activities that take place at the berths to include handling operations with ships, transporting and storing goods, and waste management from ships and the port. In addition, pollution occurs through marine shipping in the channels and waterways leading to the ports. As a result of the growth in maritime navigation traffic, pollution caused by ports and ships now directly impacts the marine environment, biological diversity, climate, food, and human health (Ng & Song, 2010).

One of the other significant causes of oil pollution is the oil used in ships. The oil used to run ships not only results in air pollution but may also be released in seawater. Moreover, accidents in the sea or ship wreckage due to collision even within marine port areas result in oil spillage throughout the gulf area (Abu-Hilal & Al-Najjar, 2004). Additional risks are ballast water discharge, biofouling, and the release of ship paint containing tributyltin compounds.

1.3 Research questions and objectives

- **Research questions**

The research questions are; What are the seawater pollution factors in the port of Aqaba? What can be done to improve the port of Aqaba's environmental diminutions and integrate more sustainability? Highlighting these questions will help with achieving the research aims and objectives.

- **Research objectives**

The main objectives of this research are to point out the following:

- Identify the factors that result in seawater pollution in the port of Aqaba.
- Build a framework of environmental indicators from different ports.
- Use the framework to conduct a map for Aqaba port in a case study and find the gaps.
- Address the gaps through recommendations dependent on the best application in the literature review.
- Minimize and mitigate the pollution at Aqaba port and integrate more on sustainability.
- Contribute to sustainability from the environmental aspect.

1.4 Research scope

The scope of the research will be to identify the factors and causes of marine pollution in the port of Aqaba, and the focus will be on the pollution of seawater only. There are many factors of seawater pollution in the port of Aqaba. Including cargo handling, waste and sewage from the port and ships, oil spills, and ballast water from ships in territorial waters. Air pollution will not be touched upon as it is not among the objectives of the research.

The procedures taken to mitigate pollution factors in the port of Aqaba will be identified, and their effectiveness will be determined. Also, the capabilities of the port of Aqaba will be ascertained in terms of the availability of necessary facilities for dealing with waste and sewage from the port and ships. Their efficiency will be assessed and studied for possible further development. Also, it will be determined how waste is transported to facilities and what possible improvement could be made to the process in the future.

It will also be within the scope of the research to get acquainted with the procedures followed in dealing with any violations of ships in the territorial waters and how to monitor any oil or chemical spills or the drainage of ballast water in the territorial waters. Several green ports will be studied, and sustainability indicators will be extracted from them to create an ideal framework. Later on, a case study will be conducted on the port of Aqaba to find gaps. After determining the gaps in the port of Aqaba, recommendations will be provided to minimize pollution and fill the gaps. Sustainability integration is going to be recommended as part of the solution.

1.5 Methodology

In scientific and academic research, many means and methods are used to prepare the research in the best way. One of the essential elements of research is the process of collecting data. The types of data are divided into two main categories:

- Primary data collection.
- Secondary data collection.

- **Primary data collection**

Primary data is basic data gathered for the first time. The primary data collection process is a bit difficult, but it is simple to examine. Semi-structured Interviews mainly will be used in this research as the primary data collection technique, where the researcher attempts to research the subject amply. Semi-structured interviews allow the researcher to deliver the questions and probably get a valuable response in return. There are a few disadvantages of using this approach; It is possible that the data collected is too enormous in a quantity that it becomes hard to interpret; also, it is possible that the responder distorts and confuses the information.

- **Secondary data collection:**

On the other hand, secondary data is data available from various sources. It is easily reachable and very inexpensive. Secondary data is authentic and available from IMO

publications, conventions, official records, documents of JMC, academic books, various sources online, and peer-reviewed journal articles. Still, it is not easy to analyze and interpret it (Hox & Boeije, 2005).

The data approach used for this research is primary and secondary data. The methodology used in this research is qualitative. A framework of indicators was built based on the literature review to address the pollution in Aqaba port from a sustainability perspective. Second, the port of Aqaba was mapped as a case study. The case study counts on documents, port website, personal experience, and three interviews with port operation managers. Third, after conducting the mapping according to the framework built, recommendations to minimize pollution and integrate with sustainability are provided as solutions.

According to the requirements of the World Maritime University (WMU), ethical issues have been taken into consideration as the data and interviews were treated with confidentiality and complete reservation.

1.6 Dissertation structure

The structure of the dissertation is a combination of different chapters ranging from Chapter 1 to Chapter 6:

Chapter 1 provides a comprehensive introduction to seawater pollution, including background, problem statement, research questions, and objectives. Also, an explanation of the research scope, clarification of the planned methodology, and the dissertation structure.

Chapter 2 highlights the literature review articles on the marine environment, seawater pollution factors and integrates the sustainable dimension of the environment in ports. It also includes the analytical framework used in the research.

Chapter 3 provides a brief introduction of the port of Aqaba and its maritime governance regarding seawater pollution, then maps the port of Aqaba as a case study to detect gaps and their size.

Chapter 4 includes the interview results and analysis facts, which assist in solutions and recommendations to mitigate seawater pollution.

Chapter 5 concludes the whole dissertation by summarizing it and describe the research limitations.

Figure 1 below shows the research flow chart.

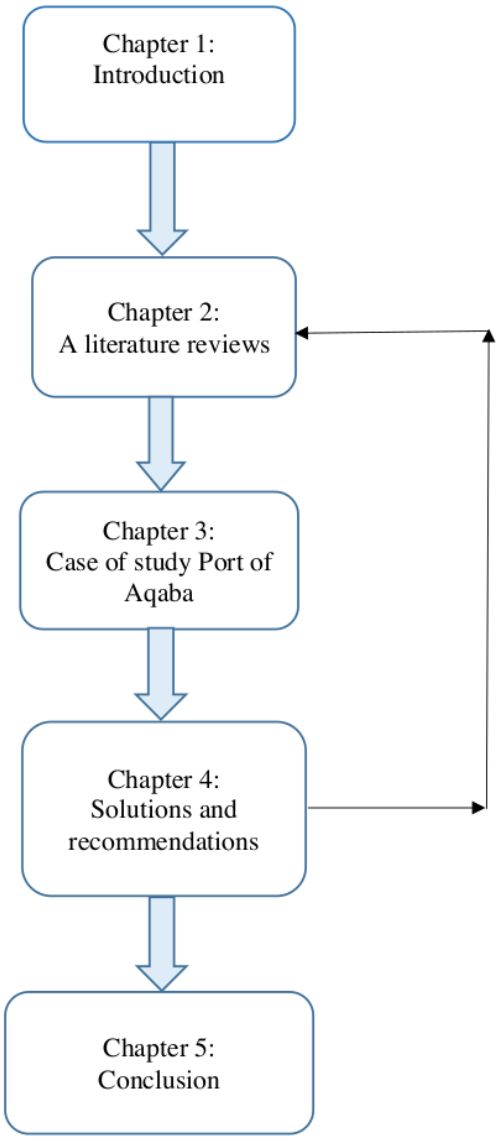

Figure 1: The research flow chart

Chapter 2: A literature review

2.1 Literature Review

- Potters (2013), in his work about marine pollution, classified the types of pollution and the way they affect the marine environment. The point source and non-point source of pollution are also described in the research work. The significant sources of pollution are represented as the following: 33% of the total seawater pollution is caused by the airborne release of toxic gases from land, 44% of marine pollution is caused by a discharge that is dumped into seawater without treatment, 1% is from offshore mining, 12% is from ship accidents and oil spills, and 10% is from ocean dumping (Potters, 2013).

- Abu-Hilal & Al-Najjar (2004), in their research work, describe the dangers of litter pollution on the Gulf of Aqaba, Jordan. The research work describes the hazardous effects of submerged seawater litter at the specific sites in the coastal area of Aqaba. After conducting different surveys and research, the total amount of litter collected from 25th August 2003, until 29th February 2004, was nearly 1159 kg. They also mention the cause and effects of this litter pollution on marine life, tourists' spots, and human health.

- Sislian et al. (2016), in their research, point out the issues about environmental protection and sustainable development around the coastal areas due to the increasing number of activities around the port. This research is mainly focused on the environmental factors that are endangered because of ship activity around the coastal areas. The significant factors that affect port sustainability are noise and air pollution, degrading disposals, and ship operations (trade, cargo loading, and discharging) (Sislian et al., 2016).

- Chiu et al. (2014), in their research, the authors point out that due to the increased movement of ships around the coastal area, the concept of a sustainable port becomes more significant. Seaports are playing a great role in the economic growth of the country; however, due to these trades, the global environment, including the marine environment, is also affected. To address this problem, they provide a solution with the use of green ports.

As mentioned previously, it is clear that the marine environment is highly vulnerable to pollution, as many sources of marine pollution result in different types of pollution. Among the sources of marine pollution are port activities and marine navigation, which is continually increasing with the increase in global trade and the increasing need for maritime transport of all kinds. Therefore, the concept of environmental sustainability becomes more important and challenging to achieve.

The protection of the marine environment by reducing the seawater pollution factors is one of the main pillars for achieving a sustainable environment and thus contributing to the integration of sustainable development. Also, the green port is one of the concepts that contribute to providing facilities and capabilities with the best standards for dealing with various types of waste generated from ships and the port.

2.2 Sustainability development and Green ports

- **Sustainability development**

In 2015, the United Nations (UN) Organization launched a program clarifying its plan towards sustainable development. Sustainable development is defined as enabling the needs of present generations to be fulfilled and their welfare achieved without prejudice to the ability of future generations to satisfy their needs, taking into account the challenges of preserving ecosystems and the limitations of renewable natural resources. Sustainable development consists of three dimensions: economic, social, and environmental (Elliott, 2013).

In 2015, the UN adopted the Sustainable Development Goals (SDGs) for the 2030 Agenda (UN, 2019). Maritime transport plays a prominent and vital role in global trade and the economy. For this reason, the IMO works dynamically and effectively on issues of sustainable development and its goals through the participation of the Technical Cooperation Committee (TCC), where it works to officially consider achieving the SDGs (IMO, 2019).

Jordan has followed the path of reform to reach SDGs, as it is a process linked to progress in all political, economic, social, cultural, and environmental fields. In the field of environment, the Environmental Division in the Statistics Department was established to achieve the process of analyzing environmental data from various locations, including sites from the marine environment, to make any necessary improvements and achieve the highest standards in the sustainable environment (DOS.jo, 2015).

- **Green ports concept**

The concept of a green port is a way to achieve the following goals: preserving biological diversity and ecological equilibrium, adopting a sustainable approach to utilizing natural resources, and improving port operations and its various activities. The point of the green port idea is the rational utilization of resources, applying investments towards the environment and technology, and modifying in the institutional manner of the port (Oniszczuk-Jastrząbek et al., 2018).

An environmental green port can be achieved by applying several measures such as introducing tree planting in the port design system, which helps in pollution mitigation and noise reduction. In addition to relying on renewable energy to carry out various activities in the port, a green port also establishes facilities to receive garbage and wastes to recycle it (Anastasopoulou et al., 2011). The desired result of the Green Port

concept is for the port's ability to meet stakeholder requirements is equal to its ability to maintain environmental sustainability.

2.3 Indicators for assessing seawater pollution factors

Achieving an Environmental port is available and possible for all ports of the world. However, it depends on factors such as the level of technological development, the level of industrialization, the geographical location, and the extent to which local legislation supports the environmental dimension in the country (Oniszczuk-Jastrząbek et al., 2018). According to Port of Koper in Slovenia demonstrated that any port could build a framework for sustainable development by some effective procedures and standards to be followed (Beškovnik & Bajec, 2015). However, it is challenging to implement these procedures in their entirety and full effectiveness. Thus, the progressive pattern of these procedures must be followed according to the conditions of each port and the priority of the procedures (Chiu et al., 2014).

Since the ports carry a group of supply chains that includes various activities and stakeholders, the ports must adopt complementary and integrative methodologies that would contribute to the sustainability of the ports and enhance the management of stakeholder relations (Denktas-Sakar & Karatas-Cetin, 2012). Contemporary sustainability approaches in port planning are restricted to particular issues, statistical data, and professional judgment for the development of the port itself; second, the sustainable port planning approach focuses on environmental issues but disregards ecological concerns (Wu et al., 2020).

There is a great opportunity to achieve environmental sustainability in Aqaba Port. However, several significant elements must be taken into consideration, including the geographical location of the port, the level of technological development available for application in the port, as well as the equilibrium between the requirements of stakeholders and environmental sustainability.

In the trends of the environmental administration of ports, and the ability of governments to pre-determine environmental sustainability in port development. The same areas of potential research include in academia to find key performance measures in a manner consistent with the operational needs of the ports themselves (Lim et al., 2019). Some indicators were achieved, such as waste pollution management, water pollution management, Ecosystem and habitats, Green port management, and Energy and resource usage.

In a case study of four ports in South Korea, indicators were chosen, such as considering environmental protection when handling cargo, avoiding the use of unpolluted land in the port area, preventing the disposal of effluents, and maintaining water quality (Oh et al., 2018). The study showed that the balance in achieving the three dimensions of sustainability, economic, social, and environmental is the best way to achieve the required level of sustainability.

By reviewing some of the experiences of ports in the field of a sustainable environment, some important indicators were reached that would assess the extent of the impact of marine pollution factors in the ports. Among these factors related to seawater pollution, the management of waste generated from the port and ships, providing various kinds of reception facilities, procedures for cargo handling, and the plans followed in dealing with several types of pollution.

2.4 The impact of seawater pollution

Harmful ecological impacts caused by environmental pollution from seaports originate from ships that connect to the port, the operations, and the activities of the port itself, and the transport networks that serve the remote areas of the port (Chiu et al., 2014). In this research, the focus on the ships that connect to the port, the operations, and the

activities of the port itself. Pollution of seawater has vast negative effects on a wide range of different parties, including:

- **The human health**

The infiltration of chemicals, oils, and other pollutants into the waters of the sea and their contact with fish and marine creatures that humans feed on cause many different diseases for the human being. The nervous system and kidneys can be damaged as a result. In addition to hormonal diseases, there are reproductive diseases related to reproduction if a person is exposed to these materials in large quantities (Hester, 2011).

- **The economy**

Many economic sectors are negatively affected by seawater pollution. This type of pollution negatively impacts ships and other elements of maritime navigation. The European fishing fleet experienced a loss of approximately $82 million. Pollution of seawater contributes to the loss of about one billion euros annually to the countries of Asia and the Pacific due to the damage to marine industries. The tourism sector loses up to $600 million annually due to this type of pollution (W S Reed, 2003).

- **Marine life**

The waste and garbage dumped in the oceans and seas, such as oil products, sewage water, industrial waste, chemicals, and plastics, have a direct impact on the behaviors and patterns of various marine organisms. The plastic decomposes into harmful substances that absorb other pollutants, which leads to harming marine life when they eat these materials (Derraik, 2002). Furthermore, the pollutant substances can transmit to humans by eating fish caught from the sea (Risjani & Sumampouw, 2014).

2.5 Analytical framework (factors that increase seawater pollution in ports and ways of improvement)

Many factors contribute to environmental pollution in general and seawater pollution in particular. Indicators are defined as the techniques for assessing the positive or

negative environmental conditions and the outcomes of the actions applied. An environmental indicator is a variable or value resulting from a set of variables that gives information on a phenomenon of higher importance than that directly linked with the configuration of the variable (Peris-Mora et al., 2005). In this context, seawater pollution factors will be used as indicators to infer the size of the impact of these factors on the marine environment in the port of Aqaba.

Some of these factors for seawater pollution from the port area include (C. Trozzi & R. Vaccaro, 2000):

- Accidental discharge of harmful substances to the marine environment such as oils and chemicals during handling operations between port and ships.
- Discharge of high-temperature water into the sea, used for cooling by industrial facilities.
- Pollution of rainwater accompanied by the waste of waiting yards and various port facilities.

As for the factors of seawater pollution due to ships, we mention some of them (C. Trozzi & R. Vaccaro, 2000):

- Accidental leakage of various fuels and oils from ships such as diesel and gasoline.
- Insufficient reception facilities at the port for waste, ship oil, and ballast water.
- Pollution resulting from washing ship's tanks from chemical and oil residues.
- The release of uncontrolled ballast water may transfer harmful organisms and pathogens.

By reviewing the literature on marine pollution and identifying the factors of seawater pollution, an analytical framework is constructed that clarifies the seawater pollution sources were divided into four main sections, in each section identifying a set of most crucial seawater pollution factors in the port of Aqaba, besides ways to improve that are commensurate with the capabilities of the port of Aqaba. Figure 2 below illustrates this framework.

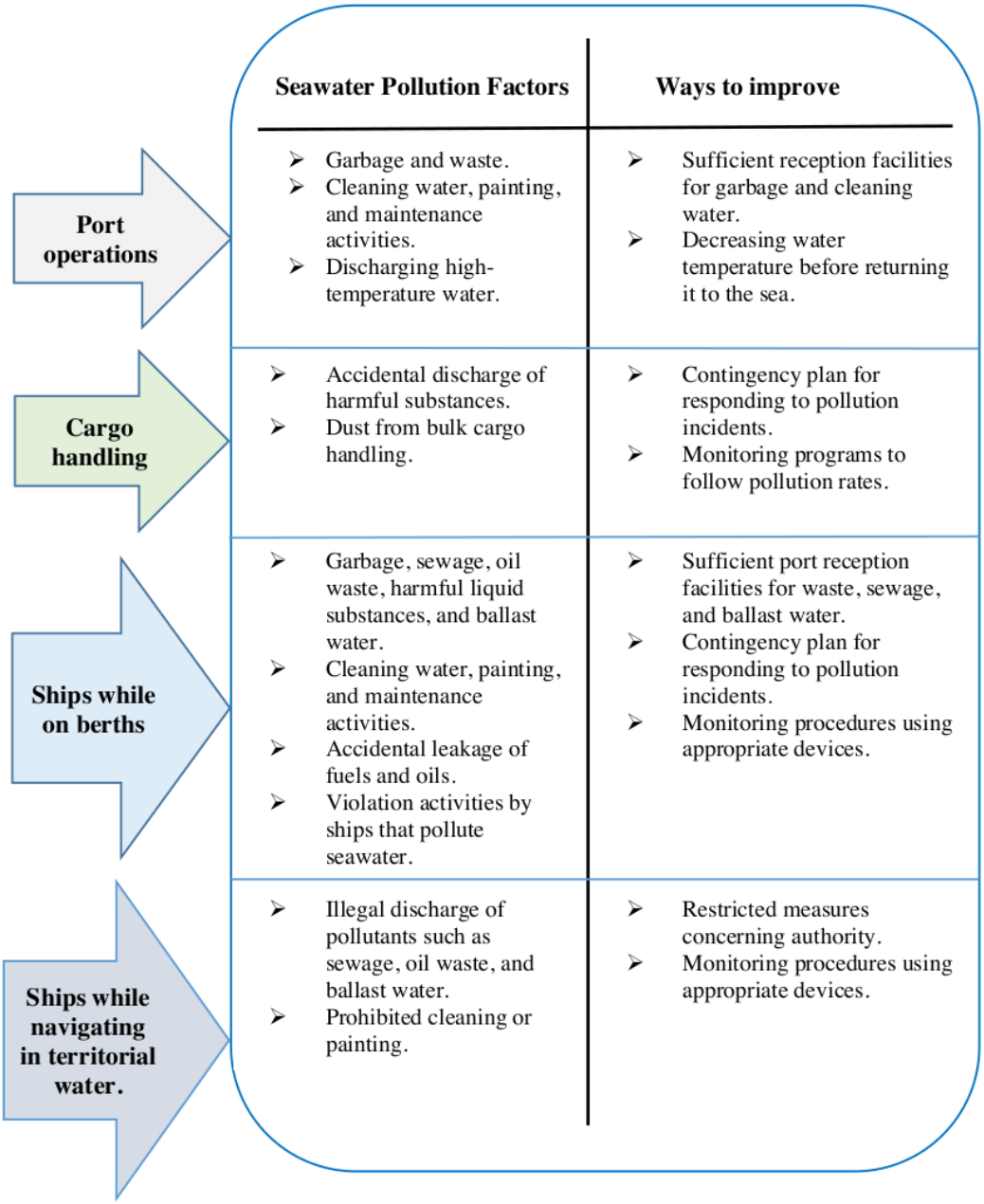

Figure 2: Analytical framework (factors that increase seawater pollution in ports and ways of improvement)

Chapter 3: Case of study Port of Aqaba

3.1 Introduction about Port of Aqaba

Maritime transport is one of the oldest means of transportation used by man because of the many economic advantages it provides. Goods and heavy goods are transported over long distances and at a lower cost than other means, which is an attractive advantage. Seaports are the main and primary outlet for the foreign trade of countries. They play an essential and vital role in the progress of economic development. Seaports are one of the most important sources of national income (Rodrigue & Notteboom, 2020). However, there are environmental impacts from seaport activities, services, and operations, such as industrial waste, solid hazardous materials, and wastewater.

The city of Aqaba is located in the far south of the Hashemite Kingdom of Jordan, 330 kilometers south of the capital city Amman. ◌Aqaba is the only coastal city in the Kingdom, as it overlooks the Red Sea from the northeastern side of the Gulf of Aqaba. Aqaba Port is the only seaport in the Hashemite Kingdom of Jordan. The Jordanian maritime border extends from the northeast of the Gulf of Aqaba towards the south at the Saudi Arabia border. The length of the coastline of Aqaba reaches 26 kilometers, and its territorial waters extend to a range of three nautical miles. It shares marine borders with Saudi Arabia, Egypt, and Israel in the far southwest.

Aqaba Port is considered to have a prominent role in developing the Jordanian economy by transporting most of Jordan's imports and exports. In addition, Aqaba Port transports goods to neighboring countries, such as Iraq, the Palestinian Territories, and Egypt. Aqaba port has witnessed steady development during the past five decades to

become one of the main ports in the Red Sea region. Figure 3 below shows the location of Port of Aqaba.

Figure 3: The location of Port of Aqaba

Source: (Google Maps, 2020)

Since its inception, the port of Aqaba has undergone several administrative and legal changes that included several names and missions. These changes took place in 1939, 1952, 1979, and the most recent in 2017, when the Jordanian government decided to transfer it from the Ports Corporation to a limited joint-stock company under full government ownership, and its name became the Aqaba Company for Ports Operation

and Management (ACPOM) (ACPOM, 2020a). However, shipping and Aqaba Port activities have a significant impact on the environment. The navigation traffic in the Gulf results in black oil spills and oil leaks into seawater. Besides, the accumulated waste and phosphate dust scattered in the Red Sea and its beach are a real threat to fish, coral, and the ecosystem. Figure 4 shows the Port of Aqaba.

Figure 4: Port of Aqaba

Source: (ADC, 2020)

3.2 Maritime governance in the port of Aqaba (seawater pollution perspectives)

Maritime governance is a dynamic approach formed by interdependent fields of environmental aspects, lawful regulations, and a blue economy. Maritime governance is an essential instrument for all powers to earn their interests. Thus, the interrelation among these interdependent fields is necessary as well (Łukaszuk, 2018). Despite Jordan's limited capabilities, it played an essential and active role in the international and national arena. Represented by Jordan Maritime Commission (JMC), Jordan has ratified many important international maritime conventions that would help achieve a safe maritime transport sector in a clean marine environment.

There are more than 35 international maritime conventions ratified by Jordan, including those concerned with preventing marine pollution, protecting the marine environment, preparing for and addressing oil pollution, and managing ballast (JMC, 2020). Below are two of the most important of these conventions and clarification about their relationship with marine pollution:

- The United Nations Convention on the Law of the Sea 1982 (UNCLOS). Jordan ratified the UNCLOS convention on 24th June 1995; consequently, Jordan is obligated to implement the provisions and articles of the convention, including Part XII, related to the protection and preservation of the marine environment.

- The International Convention for the Prevention of Pollution from Ships (MARPOL 73/78). Jordan ratified MARPOL on 2nd September 2006. MARPOL is considered one of the essential conventions aimed at preventing pollution from ships and protecting the marine environment. In addition, it provides multiple means that contribute to formulating a system for global trade in legal affairs and the shipping sector (IMO, 2011). MARPOL contains six annexes dealing with different types of pollution from ships. Each Annex

contains the regulations to address the specific kind of pollutants. Each member state should provide adequate Port Reception Facilities to deal with different types of waste from ships (MEPC, 2014). MARPOL annexes are the following:

- **Annex 1** contains regulations for preventing oil pollution.
- **Annex 2** contains regulations for preventing contamination with harmful liquid substances.
- **Annex 3** contains regulations to prevent contamination with harmful substances transported in a package.
- **Annex 4** contains regulations to prevent pollution of ships' sewage.
- **Annex 5** contains regulations to prevent pollution of ships' garbage.
- **Annex 6** contains regulations to prevent the ship's air pollution.

In the national arena, maritime governance in the port of Aqaba, which is concerned with seawater pollution, falls under three parties: the JMC, the Aqaba Special Economic Zone Authority (ASEZA), and ACPOM. Each party is responsible for a different aspect of seawater pollution.

- **JMC**

JMC is a government administration with administrative and financial independence with its main building in Aqaba city. It is directly related to the Ministry of Transport (MoT) and the Chairman of its Board of Directors, the Minister of Transport. In 2002, the JMC was established to assume legislative and regulatory tasks in the regional waters. Among its missions is to develop local maritime legislation, prepare all legal and technical requirements to raise the level of marine education and training, provide a competitive environment to promote investment, improve maritime safety and security degrees, provide all requirements to protect the marine environment, and many other tasks (JMC, 2002a). Figure 4 shows the organizational chart of JMC.

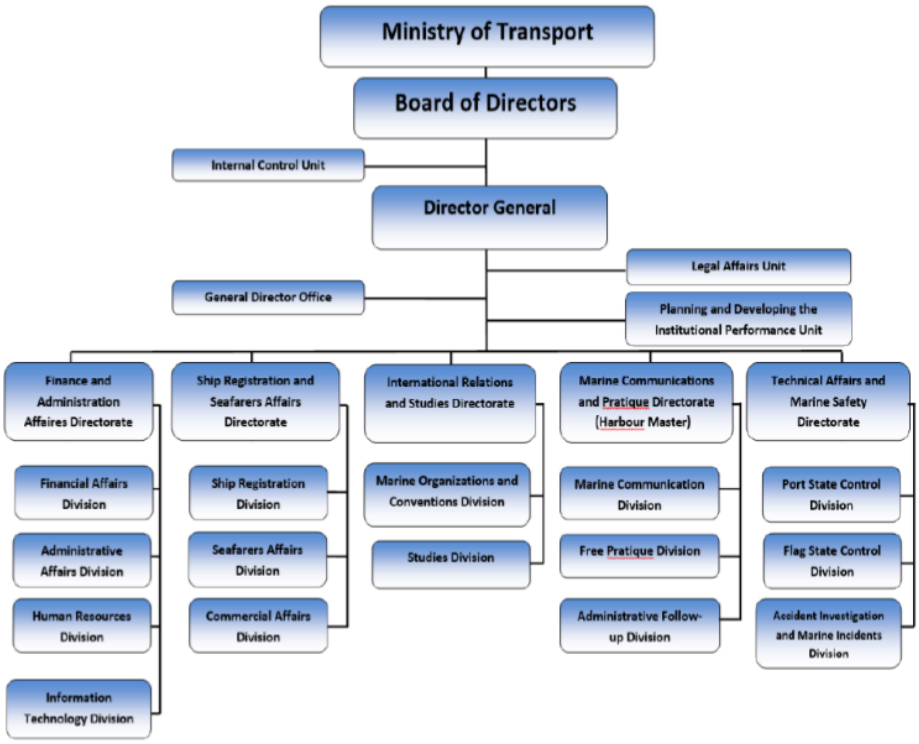

Figure 5: The organizational chart of JMC

Source: (JMC, 2002b)

The Port State Control Division and the Flag State Control Division are the relevant divisions to monitor ship pollution and implement regulations. The activities relate to:

- Wastes generated by port operations and cargo handling.
- Wastes generated by Ships while on berths.
- Wastes generated by Ships while navigating in territorial water.

JMC is the main party responsible for monitoring the applying of international instruments for preventing and managing marine pollution. As it oversees the implementation of many relevant conventions in this regard, including:

- International Convention on Oil Pollution Preparedness, Response, and Cooperation (OPRC) (IMO, 1990).

- International Convention on The Control Of Harmful ANTI-FOULING Systems On Ships (IMO, 2001).
- International Convention for the Control and Management of Ships' Ballast Water and Sediments (IMO, 2004).
- Bilateral Agreement Between EMSA and JMC For Receiving EMSA Satellite-Based Oil Spill And Vessel Detection Service (CLEAN SEA NET) (JMC, 2014).

- **ASEZA**

In 2001, the administration of Aqaba city was started as ASEZA, in a governmental direction to transform the city into a pioneering regional center. It is represented by its privileged location in the Middle East, which connects three continents, Africa, West Asia, and the Middle East, aiming to make the city a global tourist, investment, and commercial destination on the Red Sea (ASEZA, 2017). The ASEZA is considered an independent system that aims to administer the city of Aqaba and provide all forms of services that ensure a competitive environment for investment and tourism within the foundations of sustainable development.

The ASEZA is administered by six members of the Commissioners Board and their president. Each member is responsible for a particular specialty in the city. These specialties are investment affairs, administrative and financial affairs, environmental and regional affairs, city affairs, and tourism and economy affairs (ASEZA, 2000). Environmental and regional affairs Environmental Directorate is the specialty concerned with the marine environment. This department is responsible for all environmental aspects of Aqaba city and permanent coordination with the Ministry of Environment (MoE).

Among its most essential tasks is monitoring and controlling pollution of the marine environment from marine activities and operations of Aqaba port, monitoring the cooling water used by factories and plants, and creating a database to be used as a

scientific reference. In addition, it participates in the committee to follow up on the application of maritime security requirements for ships and ports; also, it forms the environmental damage assessment committee (ASEZA, 2001).

- **ACPOM**

The ACPOM is considered an essential pillar in the Jordanian national economy, as it assumes multiple tasks and responsibilities, including (ACPOM, 2020):

- Managing, operating, and maintaining the operational assets of the seaports entrusted to the ACPOM to manage, operate, and maintain them.
- Providing the necessary services for ships on the berths (cargo handling, refueling, and water supply).
- Managing and operating the yards and logistical areas in the ASEZA (ASEZA customs center\ Square 4).
- Developing operational processes and the optimal use of resources and assets available at the port.

Returning to the statistical tables of the ACPOM, you find that since the ASEZA began its work in 2001 until the end of 2017, the number of ships that passed through the port reached 47,597 ships. The total of what was dealt with was about 262 million tons, and the financial revenues of the ACPOM exceeded one billion Jordanian dinars (ACPOM, 2020).

In 1996, the Prince Hamzah Center for Combating Marine Pollution was established to protect the marine environment in the Gulf of Aqaba in general and the Jordanian territorial waters in particular by dealing with oil spills at sea and collision accidents that occur to ships. It aimed to preserve biodiversity in the marine environment famous for its beauty and distinguish it in the Gulf of Aqaba. In addition, it aimed to cooperate with neighboring countries in cleaning the Gulf of Aqaba thoroughly. This is why Prince Hamzah Pollution Control Center is considered one of the most vital components of the company (ACPOM, 2020).

3.3 The response for seawater pollution in Port of Aqaba

Usually, when any pollution in the seawater is observed at the port of Aqaba or the Jordanian territorial waters, the port control tower is notified. Anyone who witnesses this pollution can report such as fishing boats, picnic boats, or commercial ships, and sometimes marine pollution is monitored by patrols Royal Jordan Navy.

When reporting an unknown source of marine pollution occurred, an environmental damage assessment committee is formed by ASEZA with participating from JMS and ACPOM; directly, this committee goes to the location to conduct the necessary assessment and investigation, based on the results of the assessment, the necessary assistance is requested to combat pollution, and based on the results of the investigation, the appropriate action is taken, such as financial fines, technical and conservative detention, some situation transfer to the judicial courts (ASEZA, 2001). The role of the Environmental Directorate\ ASEZA is in preparing legislation and laws to prosecute the one who caused harm in the seawater and cooperates with many sectors in Aqaba to ensure the safe environmental situation and the sustainability of normal life in the Gulf waters, where ASEZA is the highest authority in the city of Aqaba (ASEZA, 2001).

The JMC duties come to monitor the enforcement of maritime legislation internationally and locally through the Port State Control Division and the Flag State Control Division, which handle the environmental dimension in the Gulf of Aqaba (JMC, 2002), while the executive body is the Prince Hamzah Center\ ACPOM through pollution control equipment such as boats and tools for confining marine pollution spots, in addition to, the tugs of Aqaba Company for Marine Services. However, many reasons contribute to the damage in the marine environment, including the long time spent reporting and determining the state of pollution, the bureaucracy of governmental procedures, and the weak administrative procedures that would reduce marine pollution.

3.4 Mapping Seawater polluting factors in Port of Aqaba (gaps analysis)

To assess the situation in Aqaba Port regarding the current condition of seawater pollution, gaps must be identified by conducting a map of pollution factors and their classification based on the analytical framework that was previously established in Chapter Tow, Section Five. The approach to identifying the gaps and their size is an approach that helps in knowing the amount of the defect by comparing the current situation to the ideal situation (Latinopoulos et al., 2018).

According to the interviews, there are variances in capabilities, procedures, and applications. Thus, and based on the four main sources of seawater pollution in the port of Aqaba, the current situation of the port of Aqaba was analyzed. A classification of each gap was given based on comparing the current situation with the ideal situation, the ideal situation represented by the ways of improvement seawater pollution factors in the port of Aqaba. The gaps classification is based on essential determinants that would clarify the extent to which the current situation at the port of Aqaba matches the ideal situation. The main determinants are, first, the capabilities and potentiality available at the port, such as Port Reception Facilities (PRF); secondly, administrative procedures and programs such as contingency plans and monitoring programs.

Therefore, providing full capabilities and effective implementation of administrative procedures indicates that the gap size is low and does not require any recommendations. If there is incomplete of capabilities or ineffective implementation of administrative procedures, the classification of the gap is medium. Finally, if there is a severe shortage of capabilities or clear obstacles in implementing the procedures, then the classification of the gap is large. The classification was expressed based on three levels of gap size; high, medium, and low, as follow:

High Gap: a gap which high important; it has to be filled.
Medium Gap: a gap which medium important, recommended to be filled.
Low Gap: a gap that may not be important probably is not critical.

Figure 5 shows the gaps analysis of seawater pollution factors in the Port of Aqaba; Below figure 5, the explanation and detail will be made for the large and medium gaps. The small gaps do not need an explanation as they are not considered critical.

	Seawater Pollution Factors	Ways to improve	Classification
Port operations	➢ Garbage and waste. ➢ Cleaning water, painting, and maintenance activities. ➢ Discharging high-temperature water.	➢ Sufficient reception facilities for garbage and cleaning water. ➢ Decreasing water temperature before returning it to the sea.	**Medium Gap** **Low Gap**
Cargo handling	➢ Accidental discharge of harmful substances. ➢ Dust from bulk cargo handling.	➢ Contingency plan for responding to pollution incidents. ➢ Monitoring programs to follow pollution rates.	**Medium Gap** **Low Gap**
Ships while on berths	➢ Garbage, sewage, oil waste, harmful liquid substances, and ballast water. ➢ Violation activities by ships that pollute seawater. ➢ Cleaning water, painting, and maintenance activities. ➢ Accidental leakage of fuels and oils.	➢ Sufficient port reception facilities for waste, sewage, and ballast water. ➢ Monitoring procedures using appropriate devices. ➢ Contingency plan for responding to pollution incidents.	**High Gap** **High Gap** **Low Gap**
Ships while navigating in territorial water	➢ Illegal discharge of pollutants such as sewage, oil waste, and ballast water. ➢ Prohibited cleaning or painting.	➢ Restricted measures concerning authority. ➢ Monitoring procedures using appropriate devices.	**Medium Gap** **Medium Gap**

Figure 6: Gaps analysis of seawater pollution factors in Port of Aqaba

- **Port operations**

The port of Aqaba includes intertwined systems in which many technical, operational, and administrative operations are carried out. The land and sea area of Aqaba port is 2060800 square meters, with an annual maximum production capacity of 28 million tons. The working hours in most of the port facilities are 24 hours a day, divided into shifts. Aqaba port has 12 different transport and discharging equipment and nine different types of warehouses with large and varied capacities (ACPOM, 2020c).

Therefore, for such a huge vital institution that includes many activities and operations, adequate facilities must be provided that deal with various types of wastes such as washing and cooling water in facilities, maintenance waste, and facility garbage. However, the interview results indicated that despite the existence of waste facilities, they are insufficient to deal with the various types of waste and their quantities, where, although the sewage and port waste system is linked to the main system of the municipality of Aqaba, there are no suitable equipment and drainage networks for the consumed water in cases such as cooling and washing, or rainwater and torrents that wash away the residual goods and waste from the port yards into the sea, according to the interview with JMC, "*the natural sources of pollution such as rainwater, and torrents which brings some pollutants from other areas one of the seawater pollution reasons in the port of Aqaba*." In addition to the fact that there is no serious commitment from the workers regarding environmental instructions inside the port. For these reasons, the gap classification is medium, where there is incomplete of capabilities.

- **Cargo handling**

The berths of Aqaba port are divided into category types according to the kind of goods and materials they handle. Most of the berths are for handling general cargo, such as bulk materials, solid materials, and cars. The second type of berth is oil and liquefied gas berths, and finally, there are industrial berths that handle phosphate and potash

(ACPOM, 2020b). There are significant challenges in the process of handling various types of goods and materials. Many kinds of these materials are highly harmful to the marine environment in case of any regulatory or application errors in the handling process. Dust resulting from handling bulk cargo such as grains, coal, sulfur, in addition to errors that may occur in handling petroleum and chemical materials, are among the main causes of pollution.

According to the interviews with both the ASEZA\ Environment Directorate and the ACPOM\ the Prince Hamzah Center, handling operations are directly supervised by public safety officials in the ports. Additionally, the staff of the ASEZA's Environment Directorate conduct continuous monitoring tours around the clock and follow up on fixed monitoring stations. From the ACPOM side, the port authority enforces the ships and the cargo agent to use plates between the ship and the quay to prevent any seawater pollution by this material. Also, a floating boom on the oil terminal is used around the ship to keep any pollutant sieged and make it easy to remove. Figure 7 shows the floating boom. In addition, cargo residuals on the quay are cleaned up after the handling process is over. Moreover, a permanent oil boom used in the oil terminal around the quay head is in place to deal with any leak, and cement barriers are used parallel to the shoreline to prevent any leakage from shore-side from reaching the sea.

Figure 7: Floating boom on the oil terminal

Source: (Oil jetty, 2020)

On the other hand, the ASEZA, represented by the Environment Directorate, collects seawater samples within the national monitoring program from 19 sites covering the Jordanian coast of the Gulf of Aqaba every month. The regulatory program contains the following elements:

- Physical elements; Temperature, pH, Conductivity, Dissolved Oxygen, Salinity, Transparency.
- Chemical elements; Inorganic substances, Nitrate (NO3), Nitrite (NO2), Ammonia, Phosphate, Silica, and Hydrocarbons.
- Environmental elements; Chlorophyll a.
- Biological elements; Enterococusi.

The results are compared to a reference point.

Additionally, the establishments that have direct contact with the sea are required to implement a self-monitoring program for the quality of seawater. All establishments, whether industrial or tourist, are obligated to implement a regular monitoring program that is provided to the Environment Directorate every month for evaluating and taking the necessary action.

All the procedures mentioned above and follow-ups would trigger mitigation measures. The interviews confirmed that the results of some violations in handling materials and goods are monitored tardily due to the slow reporting and procedures, mainly when accidents occur in the handling process. Bureaucratic procedures and government behavior to make start-up decisions take a long time. For these reasons, the gap classification is medium, where there is an ineffective implementation of administrative procedures.

- **Ships while on berths**

On-board the ship, many types of waste are generated from human activity or operating machines. Also, there are wastes for some kinds of goods and materials loaded. During ships' trips that extend for months, these wastes must be handled. Thus,

some ships partially treat these wastes on board, while seaports provide PRF to various types of wastes (CE Delft & CHEW, 2017).

According to MARPOL annexes, there is a specific PRF for each Annex, and each member state is obligated to provide the required PRF to deal with ship's waste and protect the marine environment from any harmful substance. Some research studies on developing countries that do not provide adequate PRF for the various types of ship wastes found increasing levels of pollution of the marine environment due to the illegal disposal of ship waste by discharging it into the sea (Carpenter, 2005).

The interview with the JMC showed that Jordan is committed to implementing the SOLAS and MARPOL protection regulations for the marine environment in the port of Aqaba, through Flag State and Port State control over ships. In addition, restrictive measures, such as large fines, have been taken to prevent any pollution to the marine environment. There is a private company licensed and authorized by the Jordan government/ The MoE called the Typical company to provide PRF in the Aqaba port. These facilities are limited to only three annexes of MARPOL at this stage; Annex I: Oil Pollution, Annex IV: Sewage, Annex V: Garbage. These three facilities are effective and sufficient for the ships calling Aqaba port. However, there is a necessity to provide PRF for Annex II and Annex VI of the MARPOL convention. The interview with the ACPOM\ the Prince Hamzah Center indicated that oily wastes PRF need more organizing, and PRF for ballast water will be needed. For these reasons, the gap classification is high, where there is a severe shortage of capabilities, especially in PRF for Annex II and Annex VI of the MARPOL convention.

Also, based on the interviews, in regards to monitoring procedures using appropriate devices in case of any violation activities or cleaning water, painting, and maintenance activities, the gap classification is high because of two reasons. First, there are financial problems with the bureaucratic procedures and behavior of the government to make decisions to start. Second, the process followed in dealing with any violations

by ships depends on the observations of the Aqaba Port Control, which will inform the Harbor Master. After confirmation of a breach, the Harbor Master will tell the port state control to check and take the required actions. Thus, there are clear obstacles in implementing the procedures where they take a long time and solely depend on the successful observations at the beginning, which requires more improvement.

- **Ships while navigating in territorial water**

As mentioned previously, in developing countries that do not provide sufficient PRF, some ships may illegally discharge wastes at sea. According to the interview, in Port of Aqaba, if any violations are observed from any ship, Aqaba port control will inform the Harbor Master. After confirming the breach, the Harbor Master will inform the port state control to check and take the required actions (maybe reach a decision to detain the ship). These procedures are effective in preventing the ships from any violation. However, there are challenges such as the poor communications between entities related to the violation subject, especially related to environmental violations. It takes a long time to take action on environmental violations, and each entity is unclear on their limit of authority. For these reasons, the gap classification is medium, where there is an ineffective implementation of administrative procedures.

3.5 Chapter summary

The port of Aqaba has become one of the prominent ports in the Red Sea due to rapid improvements in the past five decades. In 2017, the institution responsible for operating the port of Aqaba became a limited joint-stock company with full government ownership, and its name became the Aqaba Company for Port operations and management. Despite the advantages above, there are negative environmental impacts of the port of Aqaba, such as any seaport in the world.

Maritime governance is an integral and essential approach for all parties participating in the marine system. Jordan, represented by JMC, is mainly carrying out its duties in

the international and national arenas. The JMC, ASEZA, and ACPOM share some responsibilities about monitoring and protecting the marine environment. The Environment Directorate in ASEZA is responsible for the marine environment and in permanent coordination with the MoE. The ACPOM where it provides pollution control equipment. When observing any seawater pollution, a committee is formed to assess the environmental damage by the three parties.

The gap analysis shows that the factors of marine pollution originating from the port operations are the absence of drainage networks for consumed water for washing and cooling, and rainwater that washes away the residual of goods and waste. Thus, network systems must be provided to drain this contaminated water; also, the gap analysis showed the workers' non-compliance with environmental instructions inside the port. For the factors of marine pollution originating from cargo handling, the gap analysis clarifies that there is a slowdown in procedures and reports when any violations or accidents occur in the process of handling goods, and this is the result of bureaucracy in government procedures that take a long time to make a decision; thus, it is necessary to find administrative solutions for making decisions quickly in response to any type of marine pollution, as it is not possible to delay in such situations.

As for the marine pollution factors originating by ships on the berths, the gap analysis shows that there is no PRF for Annexes II and VI of the MARPOL convention. Also, the PRF for Annex I need more regulation. Moreover, the gap analysis indicates that the flaws in the monitoring process and procedures to follow up on any marine pollution are the bureaucracy in government procedures and considering the observation as the only way to know about any marine pollution. Finally, for the marine pollution factors originating by ships while navigating in territorial water, the gap analysis shows a weakness in communications between the concerned authorities regarding marine pollution and a lack of clarity about the limits of the authority for each concerned party.

Chapter 4: Solutions and recommendations

4.1 Stakeholders perspectives on recommended solutions (interviews with port authority, operator, etc.)

Appropriate solutions and recommendations must be reached in the case of the port of Aqaba to fill the gaps mentioned previously, which contribute to protecting the marine environment and integrate sustainable development through improving the environmental dimension in the Aqaba port area. Consequently, it turns out that among the main problems are the defect in the port's waste management and dealing with seawater pollution, which includes a particular program to monitor, follow-up, and develop processes at the port by port operations, cargo handling, and ships while on berths. Also, how seawater pollution is monitored and how to respond to them by ships navigating in territorial waters and ships while on berths either purposed or not, where further improvements and modifications are needed.

A couple of interviews were conducted with stakeholders; JMC, ACPOM, and ASEZA. The interviews were semi-structured, which provided an opportunity to engage in a detailed discussion that helped drawing a comprehensive picture of the marine environment state in the port of Aqaba. In the interviews, several main axes were discussed: First, the main factors causing seawater pollution in the port area and how to deal with it. Second, the PRF available by the port, their effectiveness, in addition to monitoring any seawater pollution caused by ships navigating in territorial waters. Third, solutions and recommendations to improve the protection of the marine environment in the future.

The interviews helped identify most of the gaps; as indicated in the previous chapter, some solutions and recommendations were presented that contribute to filling these gaps. Interviewers specifications are projected below in table 1:

Table 1: Interviewers specifications

Interviewers	Professional field	Experience
JMC	Port State Control Division	25
ACPOM	Prince Hamzah Center for Combating Marine Pollution	17
ASEZA	Environmental Assessment and Monitoring Division	16

We have identified the following solutions and recommendations:

- **Port operations**
  - Increase facilities to deal with various types of port wastes and provide suitable equipment and drainage networks for the consumed water in cases such as cooling and washing, or rainwater and torrents that wash away the residual goods and waste from the port yards into the sea.
  - Spread awareness and education among workers in the port of Aqaba to raise the concept of protecting the environment culture.
  - Activate the system of deterrent penalties for port workers to control and mitigate violations that cause seawater pollution.

- **Cargo handling**
  - The orientation to the decentralized approach in implementing contingency plans and responding to marine pollution incidents.
  - Reduce the free fall of the cargo as much as possible during the handling process.
  - Use water spraying or covered storage to suppress the dust.
  - Increase storage facilities, especially for bulk materials, to control dust emissions.

- **Ships while on berths**

  - Expedite the preparation of PRF to receive ship waste for Annex II and Annex VI of the MARPOL convention, contributing to more effectiveness in implementing international regulations.
  - Use marine pollution detection devices in case of suspicion of any breach, such as rapid biological and chemical assessment.
  - The orientation to the decentralized approach in implementing contingency plans and responding to marine pollution incidents.

- **Ships while navigating in territorial water**

  - Use marine pollution detection devices in case of suspicion of any breach, such as rapid biological and chemical assessment.
  - Establish an exact protocol for the communications process and its priority between the competent authorities when reporting pollution.
  - End the problem of overlapping powers and clarify the responsibility of each party by determining the powers of each party to be integrated without any overlapping.

4.2 Policy Recommendations

There are recommendations to support a comprehensive policy for assessing and protecting the marine system, which would minimize the pollution of seawater and protect the marine environment. According to the interviewers, implementing participatory and integrative management is based on the involvement of all stakeholders and the Ecosystem (UN-NGLS, 2014). Thus, practical cooperation between the main parties, such as JMC, ACPOM, and ASEZA, is necessary to achieve the best outcomes. It is obvious from the interviews that there is an overlap in authorities and responsibility ambiguity. Especially in the environmental aspect, there is no specific and clear protocol to deal with the problems of the marine environment.

Furthermore, the author provides some recommendations; First, research studies should be conducted on ships visiting the port of Aqaba to know the quantity and types of waste generated during their voyages will help provide a clearer picture to the concerned authorities and stakeholders about the planning process and waste management in the port and the carrying capacity of the PRF that must be secured in the port (CE Delft & CHEW, 2017).

Second, strengthen communication between JMC, the competent authority for inspection, and ACPOM, the competent authority for managing the port. Thus, is the experience of the ports of Amsterdam and Rotterdam, which activated an electronic system that assists the inspection authority examing any inconsistencies in dealing with ship waste, where it has been found that the port authority tries to spare ships any conflict with the inspection authority (Øhlenschlæger et al., 2013).

Third, the Port of Aqaba might benefit from the Danish experience in this context, which imposed administrative fines on ships based on strong suspicion only regarding the illegal disposal of waste into the sea, as there is difficulty in finding evidence of such violations (Øhlenschlæger et al., 2013). Therefore, there is an urgent need to apply more stringent measures with ships navigating in territorial waters if they cause intentional marine pollution and violate laws and regulations. Other recommendations include improved inspections procedures and reporting requirements relating to how a ship deals with its waste, an enhanced regulatory framework for notification, and improved techniques for inspecting ship waste documents such as records and certificates.

Finally, the observation process is not sufficient to monitor marine pollution; more measures must be added, such as encouraging the local community picnic and fishing boats, to immediately report any marine pollution that is noticed and increase the monitoring patrols in territorial water to monitor any violations that lead to pollution.

Technology can also detect seawater pollution, using remote sensing technology to monitor pollution and describe it as type, quantity, and location at record speed. The use of technology is much better than the traditional method, which requires taking samples from different depths, transporting them to laboratories, and examining them by qualified staff. Therefore, introducing technology into the environmental monitoring process to control any pollution is one of the most important recommendations for protecting the marine environment (Loughland & Saji, 2008).

Moreover, many recommendations could be as a policy to contribute towards sustainable development, including the establishment of a system to recycle ship and port waste. A waste recycling approach is a supportive approach to sustainable development through the environmental pillar by reducing or even ending waste, which contributes to protecting the environment, and through the social pillar by creating job opportunities for the local community and motivating investors specialized in waste management and recycling. Ultimately, improving the policy followed in the port of Aqaba contributes considerably to protecting the marine environment. Thus, it is necessary to benefit from the experiences of seaports around the world in this regard. However, many challenges must be overcome through joint work by all concerned parties and stakeholders.

4.3 Chapter summary

Finding effective solutions and recommendations for marine pollution factors in the port of Aqaba contributes to improving environmental sustainability and integrating sustainable development. Therefore, and according to the interviews, solutions were proposed by stakeholders, including; providing all types of PRF at the port, educating workers on the importance of preserving the marine environment, adopting a decentralized approach in emergency plans, increasing storage facilities for bulk materials, and using mechanisms to reduce proliferation dust, the use of marine pollution detection devices, setting a specific protocol for the communication process

between the competent authorities, and ending the problem of overlapping powers between the competent authorities.

The policy recommendations that would reduce seawater pollution and protect the marine environment involve all stakeholders, such as JMC, ASEZA, and ACPOM, in integrated and participatory management that will end the overlap in responsibilities between the competent authorities in the environmental field. Second, studies on ships visiting the port of Aqaba to find out the carrying capacity of PRF must be provided at the port. In addition, strengthening communication between the inspection authority JMC and the port authority ACPOM through electronic systems will improve the speed and efficiency of dealing with ship waste.

Third, strict procedures should be implemented with ships that cause marine pollution by imposing administrative fines as soon as there is a strong suspicion of throwing waste into the sea, also, strengthening the regulatory framework for notifications about the ship's handling of its waste, and improving techniques for examining ships' waste records and certificates documents. Finally, the local community must be encouraged to report any potential marine pollution immediately. Also, remote sensing technology can be used to detect seawater pollution. In addition, an established ship and port waste recycling system would contribute to sustainable development.

Chapter 5: Conclusion

5.1 Summary of the dissertation

This research highlights the seawater pollution factors in the seaports, where the increase in global trade year after year led to an increase in shipping traffic and thus an increase in the operational volume of seaports around the world. The port of Aqaba, like other ports, faces increasing challenges in protecting the marine environment, especially with its remarkable development in recent decades and its emergence among the ports of the Gulf of Aqaba. Jordan has taken the path of reform in all different fields to achieve SDGs, especially marine environment sustainability. There are future goals to convert the port of Aqaba into a green port. As a start, improving the environmental dimension by protecting the marine environment and preventing seawater pollution will contribute to actual progress in this direction.

Literature reviews have shown that the marine environment is highly sensitive to various types of marine pollutants, which leads to increase challenges in achieving the concept of environmental sustainability, especially in seaports. Therefore, the main indicators of seawater pollution factors in seaports were identified by reviewing previous port experiences, such as; the management of waste generated from the port and ships, providing various kinds of reception facilities, procedures for cargo handling, and the plans followed in dealing with several types of pollution. Consequently, an analytical framework was built that clarifies the main sources of seawater pollution, and each source is divided into a group of marine pollution factors as indicators, as well as suggested means to reduce the impact of these factors.

Chapter 3 explains that maritime governance in Jordan concerned with the seawater pollution falls under three main parties; JMC, ASEZA, and ACPOM, where JMC responsible for the official representation of Jordan at the international level and

responsible for monitoring enforcement of maritime legislation internationally and nationally. ASEZA considers the highest authority in the Aqaba city, where through the Environment Directorate, it prepares legislation and laws to protect the marine environment in Aqaba. As for the executive body, Prince Hamzah Pollution Control Center\ ACPOM provides pollution control equipment. Therefore, when observing any seawater pollution at Aqaba port or Jordanian territorial waters, a committee will assess the environmental damage by the three parties, as this committee works on the necessary evaluation and investigation. Accordingly, the required measures are taken.

Based on the analytical framework, Port of Aqaba conducted as a case study by using gap analysis to map the seawater pollution factors. The gap analysis clarified the current environmental situation of seawater in the port of Aqaba. According to the interviews, it was found that there are various gaps in the main pollution sources, which are as follows:

- **Port operations**; The lack of proper drainage networks for the consumed water, and non-compliance of workers with environmental instructions inside the port.
- **Cargo handling**; Bureaucracy in government procedures takes a long time to make a decision and leads to slow procedures to respond when marine pollution occurs.
- **Ships while on births**; The absence of PRF for Annexes II and VI of the MARPOL convention, also, the defect in the monitoring process and procedures to follow up on any marine pollution, considering the observation as the only way to know about any marine pollution.
- **Ships while navigating in territorial water**; Weak communication between the concerned authorities regarding marine pollution, and the lack of clarity of the authority limits for each party concerned.

Solutions and recommendations have been proposed by stakeholders in chapter 4 to reduce marine pollution in the port of Aqaba; they need financial allocations to provide some of the facilities and equipment, in addition to improvements in the management approach used to combat marine pollution. However, the proposed solutions are practical, and their application is available within the existing capabilities.

Finally, recommendations were made to improve the policy followed in the marine environment; These recommendations included improving the management approach, clarifying responsibilities, strengthening communication between competent authorities, and conducting the necessary studies on ships visiting the port of Aqaba. Also, strict procedures should be implemented with ships that cause any harm to the marine environment and engaging the local community with protecting the marine environment.

In conclusion, this research presented the marine pollution factors in the port of Aqaba, and their impact on the marine environment, also clarifying the relation between the competent authorities with each other and how they respond to any marine pollution. The gap analysis helped clarify the defects and size of seawater pollution indicators. Consequently, appropriate solutions were suggested by stakeholders. Despite the significant challenges, there is a real opportunity to implement the proposed solutions and recommendations in Port of Aqaba.

5.2 Limitations

Despite making all possible efforts, perfectionism is challenging to achieve, especially in conducting scientific research. Therefore, there were limitations in the research process. In the seaports area, many aspects can affect sustainable development, but it was difficult to cover them fully. Similarly, it was challenging to cover the environmental dimension fully; thus, the focus was on the marine environment by determining the seawater pollution indicators.

The research highlighted the Port of Aqaba, which consists of multiple types of berths. However, the container port includes three large berths, was not addressed. It would have been better to include the container port to set a comprehensive plan to combat seawater pollution and provide integrated protection for Jordanian territorial waters. The container port has an independent private administration with difficult precautions and requirements that make the research process very difficult, in addition to the fact that the cargo handling system and the operational process is unique and special way in the container terminal.

Finally, the Covid-19 pandemic has had a significant influence on the research process and data collection. In my country, Jordan, very strict measures have been taken to limit the transmission of infection; for example, the closure and postponement of many kinds of normal human activities. These strict measures prevented further interviews and diversification of data sources, which would have drawn a more comprehensive and more precise picture of the status of Aqaba port. However, despite the mentioned limitations, the research achieved the desired objects and provided what is available to mitigate the weaknesses.

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