Mediterranean Smart Cities Conference (MSCC 2024)
2-4May, 2024, Martil, Morocco

Port Waste Management: Comparative Study of Ship Generated Waste System

Anass Hamraoui
Laboratory of Engineering Research (LRI)
National Higher School of Electricity and Mechanics (ENSEM), Hassan II University
Casablanca, 20100, Morocco
anass.hamraoui.doc22@ensem.ac.ma

Saad LissaneElhaq
Laboratory of Engineering Research (LRI)
National Higher School of Electricity and Mechanics (ENSEM), Hassan II University
Casablanca, 20100, Morocco
s.lissane@ensem.ac.ma

Hamid Ech-Cheikh
Laboratory of Engineering Research (LRI)
National Higher School of Electricity and Mechanics (ENSEM), Hassan II University
Casablanca, 20100, Morocco
h.echcheikh@gmail.com

Mohammed CHAOUI
Laboratory of Engineering Research (LRI)
National Higher School of Electricity and Mechanics (ENSEM), Hassan II University
Casablanca, 20100, Morocco
m.chaoui@ensem.ac.ma

Ahmed Loukili
Laboratory of Engineering Research (LRI)
National Higher School of Electricity and Mechanics (ENSEM), Hassan II University
Casablanca, 20100, Morocco
loukili2000@gmail.com

Abstract—**The environmental footprint of maritime waste becomes increasingly significant as global trade and shipping activities continually expand. This paper thoroughly examines port waste management in the context of circular economy principles, underscoring the vital need for sustainable practices in the maritime sector. It provides a comprehensive global comparative study of various Port Waste Management Plans, detailing the adopted waste reception facilities. The research framework also explores international regulations governing port waste management and offers insights into the process of port waste management.**

Keywords—Port Reception Facilities; Port Waste Management Plan; MARPOL; Circular economy; Comparative study.

I. INTRODUCTION

The maritime industry plays a pivotal role in global trade and economic development, connecting nations through sea routes [1]. However. the growth of this sector comes with environmental challenges. particularly in the management of waste generated by vessels and port activities. As we navigate the seas of progress, embracing a circular economy approach in port waste management becomes increasingly imperative.

Ship waste poses a significant threat to the marine environment. The hazardous substances present in ship waste have detrimental effects on the survival of aquatic organisms. In contrast, waste degradation can compromise water quality and disrupt the natural self-purification processes. Moreover. certain ship waste may accumulate on the seabed, altering the living conditions of marine organisms [2].

A circular economy aims to minimize waste and make the most of resources through a closed-loop system of design, production, consumption, and recycling. In the context of port waste management, applying circular economy principles becomes a strategic solution [3]. This involves not only addressing the environmental impact but also creating economic opportunities by treating waste as a valuable resource. Effectively managing waste generated by maritime activities is a crucial aspect of sustainable port operations. Ports are vital hubs for global trade and transportation, playing a pivotal role in economic development. However, the maritime industry's waste, encompassing various forms such as solid waste, oily waste, sewage, garbage, and hazardous materials, poses environmental challenges that necessitate strategic management. This paper explores the dynamic landscape of ship-generated waste management, considering the principles of circular economy, environmental sustainability, and international regulations.

II. LITERATURE REVIEW

In the contemporary era, logistics experts have identified transportation and supply chain management as prominent sources of environmental pollution, marking them as some of the most environmentally burdensome facets of logistics operations [4].

The maritime sector facilitates global trade and shipping, providing a cost-effective means of transportation in our rapidly globalizing world. Although ports play a pivotal role in fostering global economic and social connectivity, but the operational activities within ports can exert significant and diverse environmental impacts [5], [6]. In fact, ports contribute to extensive pollution across various dimensions, encompassing emissions into the air, discharges into seawater, soil and marine sediment, waste generation, and improper disposal practices [7],[8]-[6]. Without forgetting that the port and the city engage in numerous interactions. each being indispensable to the other. This approach is essential as waste generated in the port can adversely impact coastal communities. Conversely. Urban activities may have repercussions on port environments [9].On the one hand, Ulnikovic et al. [10] introduce a methodical approach for estimating average waste quantities associated with port and shipping activities, focusing on their assessment. The methodology relies on information extracted from surveys and interviews, covering key parameters such as vessel types and traffic volume. A set of criteria is applied to ascertain the number of passengers and crewmembers and categorize the quantities of waste generated by vessels, encompassing sewage, bilge and sludge and solid and oil waste. The data obtained underscore the imperative need for an organized waste management system, Setting the groundwork for addressing the complexities of waste management within the maritime sector. The port waste management system, as meticulously defined. Encompasses critical elements, including environmental impacts and aspects, organizational structure, delineation of responsibilities, training requirements, targets, and operational control measures, as asserted by Romeela Mohee et al. [11]. This comprehensive framework was established through a systematic approach. A survey form was specifically designed and utilized to collect data from 35 targeted organizations. It extended its reach to encompass a thorough examination of waste generation and flow from ships and within the industrial port area. On the other hand. Deja et al. [3] analyze and assess the existing structure of a port in the context of a circular economy to develop new models through solutions recommended to implement measures and to directly diminish the transportation of untreated waste within urban and maritime environments.

Spadaro et al. [9] also used SWOT analysis to assess waste management performance in Ports. However. Puig et al. [12] chose the Self Diagnosis Method (SDM) of 97 ECOPORTS members established by the European Sea Ports Organization (ESPO). It allows port managers to evaluate the performance of environmental management periodically and the improvement of their ports over time. ECOPORTS members answer the questions of a survey every two years. Consequently, the findings revealed that most surveyed ports had implemented an environmental policy, with more than 70% of these ports having instituted a comprehensive environmental monitoring program specifically dedicated to managing port waste.

III. METHODOLOGY

In addressing the pressing global challenge of port waste management. A robust research methodology is crucial to unearth the intricacies surrounding waste disposal and environmental preservation. This study employs a qualitative research design, recognizing the nuanced nature of port waste management practices and the need for a comprehensive understanding. The qualitative research methodology is inherently well-suited for capturing the complexities and contextual nuances that define the landscape of port waste management. Through this lens, we aim to unravel the underlying factors influencing waste management decisions, the effectiveness of current practices, and the challenges encountered by ports of varying scales and locations. By adopting a qualitative stance, we position ourselves to delve into the qualitative aspects of waste management.

The core element of our methodology involves data collection methods, namely document analysis, which will offer an in-depth review of official documents, waste management plans, environmental impact assessments, and relevant regulatory frameworks. This approach ensures a holistic understanding of formalized and practical dimensions of port waste management strategies. This study incorporates a comparative study framework, analyzing multiple ports globally to draw meaningful comparisons and insights. A comprehensive selection of ports from diverse geographical regions was crucial to ensure a representative global perspective. Criteria for selection included port location, type and quantity of waste, and regional variations in waste management regulations, Data collection involved a combination of existing Port Waste Management Plans, reports, and publications related to each selected port.

The study focused on evaluating common elements across Port Waste Management Plans, including waste reception facilities. The regulatory context in which each port operates, types of waste and involvement of various stakeholders within each port.

IV. REGULATORY FRAMEWORK

Port waste management predominantly falls under the purview of national regulations. Diverse national and regional rules govern them. This study places a primary emphasis on international regulations. Given the global context and the comprehensive scope of the research spanning different regions worldwide, particular attention is directed towards the international legal frameworks that play a pivotal role in global shaping and standardizing port waste management practices.

In order to prevent marine pollution issued from ships, many international conventions have been crafted. Such as the United Nations Convention on the Law of the Sea, which encourages countries through Part XII to Protect and Preserve the marine environment providing types of pollution and proposing measures to monitor and control it [2]. However. The key convention that significantly influences port waste management practices is the International Convention for the Prevention of

Pollution from Ships (MARPOL 73/78), which aims mainly through its six annexes to safeguard the marine environment by preventing and limiting the discharge into the sea of harmful substances and waste from ships, it targets explicitly to reduce of ship waste discharge into the sea. The six Annexes cover specific aspects as follows:

- Annex I: Regulations for the Prevention of Pollution by Oil.
- Annex II: Regulations for the Control of Pollution by Noxious Liquid Substances in Bulk.
- Annex III: Prevention of Pollution by Harmful Substances Carried by Sea in Packaged Form.
- Annex IV: Prevention of Pollution by Sewage from Ships.
- Annex V: Prevention of Pollution by Garbage from Ships.
- Annex VI: Prevention of Air Pollution from Ships.

MARPOL 73/78 also constitutes a comprehensive framework addressing waste management both onboard vessels and the reception of waste in ports through the provision of adequate waste reception facilities. Especially annex V, that establishes required provisions for reception facilities and garbage management plans [2].

Highlighting another significant convention that deals with ship ballast sediment disposal management and associated plans for sediment management, those sediments present an actual risk to the human and environment because of the huge possibility of the existence of harmful aquatic organisms, along with a considerable concentration of heavy metals, they are found in ballast tanks accumulated during ballasting operations on the tanks bottom and inner structures of the ship. To manage those sediments, the IMO introduced in the early 2004 Ballast Water Management (BWM) Convention, which in its 5th Article establishes comprehensive rules governing sediment reception facilities within ports, emphasizing that sediments should be handled as any other waste generated from ship activities. Moreover. The convention is supported by the Marine Environment Protection Committee. MEPC 152(55) Guidelines for sediment reception facilities (G1) issued by the IMO in 2006. Additionally, Regulation B-5 of the BWM Convention outlines stringent requirements for sediment management on ships, emphasizing environmentally safe disposal practices [13].

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal primarily addresses the transboundary movement of hazardous wastes, including their proper management and disposal. While the convention itself doesn't specifically focus on port waste management, but there are potential intersections. Particularly when it comes to the classification and movement of hazardous wastes. The Basel Convention classifies certain wastes as hazardous, and this classification may include some types of waste generated in ports.

V. PORT RECEPTION FACILITIES (PRFS)

A. Importance and adequacy

Port reception facilities are crucial for effective waste management in the maritime sector. They play a pivotal role in preventing waste discharge into the sea. The provision of such facilities is required by MARPOL 78/73 Convention. Consequently the states that have signed the convention should ensure the availability of those facilities once they ratify it. It includes the planification and implementation of adequate PRFs, surly according to various factors such as:

- Waste characteristics, including waste types and quantities, apply to both port wastes and those generated by ships.
- Ship characteristics refer to ship size, traffic, and kinds of activities (commercial, fishing boats, etc.).
- Size, location, and capacity of the port.
- National regulations and strategy of the state toward port waste management [14].

PRFs can differ across various ports and terminals, their specifications being established following an evaluation of user requirements and the frequency of utilization. According to the standards of ISO 16304:2018, there are three types of PRF as shown in Table I.

TABLE I. TYPES OF PRFS

Types of PRF	**Floating**	**Mobile**	**Fixed facility**
Examples	-Barges	-Vehicle -Borne -Tank trucks	-Containers -Collection bins
Advantages	-Ample capability to cater to multiple ships -Facility of access in most port areas	-Fast and flexible	-Collection of multiple types of waste. -Larger collection and storage capacity
Disadvantages	-Risk of leakage during transfer of oily or noxious liquid mixtures	-Limited when servicing large ships	-Significant investment cost -Limited accessibility by ships

MARPOL mandates the provision of adequate PRFs that must meet the needs of ships regularly using the port without causing undue delays. Also, the IMO has adopted The Global Integrated Shipping Information System (GISIS) Port Reception Facilities Database (PRFD), which compiles data on reception facilities for all

categories of waste generated by ships. Additionally, *the* MARPOL Convention ratifying states must register information about available PRFs in their ports in the PRFD to enhance the reporting rate of observed inadequate reception facilities, promoting a more effective treatment of the issue.

B. *Comparative Overview of PRFs*

A comprehensive comparative overview of different PRFs adequacy has been done. We chose two different ports from two different countries, so, we started with Bangladesh, which None of its ports has fully complied with MARPOL guidelines regarding PRF, even though Bangladesh is a party to MARPOL. Chittagong port, the largest port in Bangladesh has established a local unit that addresses aspects of waste collection, management, and treatment, but it falls short of being a comprehensive facility. On the other hand. Mongla Port one of Bangladesh's ports has devised a local mechanism by licensing vendors appointed by the port authority. These vendors manage waste using their facilities. Nonetheless, this approach proves to be insufficient for a port of Mongla's scale [14].

Conversely. The UK, as a party to MARPOL (which judges the adequacy of facilities by the number of complaints made by ship owners relating to individual facilities), has generally presumed the adequacy of provided facilities within its ports based on the limited number of complaints that have been received. However, the Maritime and Coastguard Agency (MCA) acknowledges that complaints may not be a reliable indicator of the adequacy of waste reception facilities. It explains that some inadequate facilities may go unreported for various reasons. These include the reluctance of some ship's masters to report deficiencies due to fear of repercussions, limited time for dealing with lengthy procedures, and in some cases a lack of awareness of the complaint's procedures. Additionally, complaints are less likely unless the Master is a regular port user. The MCA is considering updating the complaints procedure in the context of port waste management planning. One suggested approach, endorsed by the Port of London Authority, involves issuing cards to ship's masters to solicit comments on the adequacy of port waste reception facilities [15].

VI. PORT WASTE MANAGEMENT PLAN

A. *Development and Implementation*

The Port Waste Management Plan (PWMP) is a comprehensive document created by a port or terminal, consolidating their strategy for port waste reception facilities and delineating the available facilities. It plays a crucial role in achieving sustainable waste management by providing an overview of all waste generated, along with treatment options. This plan contributes to the implementation and achievement of waste management policies and targets at the national, regional, and international levels. Its primary objective is to enhance the accessibility, adequacy, and utilization of reception facilities. The competent authority is responsible for evaluating the PWMP to national legislation. In cases where mandatory components are insufficiently covered, approval will be withheld, requiring port authorities to justify prompt rectification. Regular comprehensive reviews of PWMPs, (occurring every 3 to 5 years) are crucial, particularly amid noteworthy changes in port operations. Such changes encompass variations in ship numbers or types, infrastructure developments, port reception facility modifications, or new onboard waste treatment methods [16].

B. *Comparative overview of four PWMPs*

Accessing (PWMPs) for various ports worldwide is challenging as these documents are often proprietary and may not be publicly available. Additionally, access to detailed PWMPs may be restricted due to security concerns of port authorities. However, we conducted a comparative study of four PWMPs as shown in table II, considering various aspects:

- The regulatory context in which each port operates.
- Types of waste.
- Infrastructure and facilities available in each port for waste reception
- Involvement of various stakeholders

TABLE II. COMPARATIVE STUDY OF FOUR PWMPS

PWMPs Location	**Mekong River ports**	**Isle of Man ports**	**PORT OF LOWESTOFT**	**Abu Dhabi ports**
Regulatory Framework	The Public Health Act B.E. 2535 (1992).	MARPOL 73/78; OPRC Regulations 2000; Public Health Act 1990; Import & Export of Waste Regulations; Water Pollution Act 1993 Part 2.	MARPOL 73/78; The Merchant Shipping and Fishing Vessels (Port Waste Reception Facilities) Regulations 2003; The Environmental Protection Act 1990; The Animal By-Products Regulations 2005; The Landfill Regulations 2002.	MARPOL 73/78, Regional Organization for the Protection of the Marine Environment (ROPME) Regulations.
Types of waste	Oily Wastes Noxious Liquid Substances; Sewage; Garbage.	Domestic, Metal, Fish, Offal, Netting, Rope, Oil, garbage, sewage, operational waste (combustible) and scrap	Oily Wastes Noxious Liquid Substances; Sewage; Garbage.	Oily waste, Noxious liquid substances, Sewage, Cargo-associated waste, Maintenance waste.

		(non-combustible).		
Port Reception Facilities	Containers.	Euro Bins, Skips, Waste Oil Tanks.	Road tanker, Bins, containers.	Road tanker, suitable containers.
Stakeholders Involvement	Unspecified	Shipping Agents; harbor keepers; Port Manager	Ship agent; waste contractor; ABP's (ASSOCIATED BRITISH PORTS) Operations Manager; Natural England; Sea Fisheries Committee; Maritime & Coastguard Agency; Environment Agency; Local Authorities; Department of the Environment; Fisheries & Rural Affairs	Ship agent; waste contractor

VII. WASTE MANAGEMENT PROCESS

Even though there are many similarities in the waste management processes of ports, establishing a model process appears complex due to various factors. These factors include different stakeholders, collection policies, treatment locations and methods whether within or outside the port area. Additionally, variations in (PRFs), notification systems, and procedures contribute to the intricacy.

In comparison to waste management plans across various ports. We have developed a standardized process "fig 1" for effective waste management, beginning with the arrival of ships at the port. They should notify the port authority of the type and quantity of waste landing in the port at least 24 hours before arrival by a declaration form. If the waste intended to land contains oily waste, cargo residues, or hazardous waste. Then the shipping agent should arrange waste reception with an approved waste contractor. In contrast, if waste includes only ordinary garbage. The port makes the arrangement of provision. After the waste is landed, ships are called to report any inadequacies in the waste reception facilities provided. In the end all ships pay a mandatory Waste Management Charge, and the port maintains records of the waste quantities declared by ships for both landed and retained waste onboard. These declared quantities are then cross-referenced with the figures reported by waste contractors for the actual waste landed in the port. However, an Authorized Waste Treatment Company generally does waste treatment outside the port.

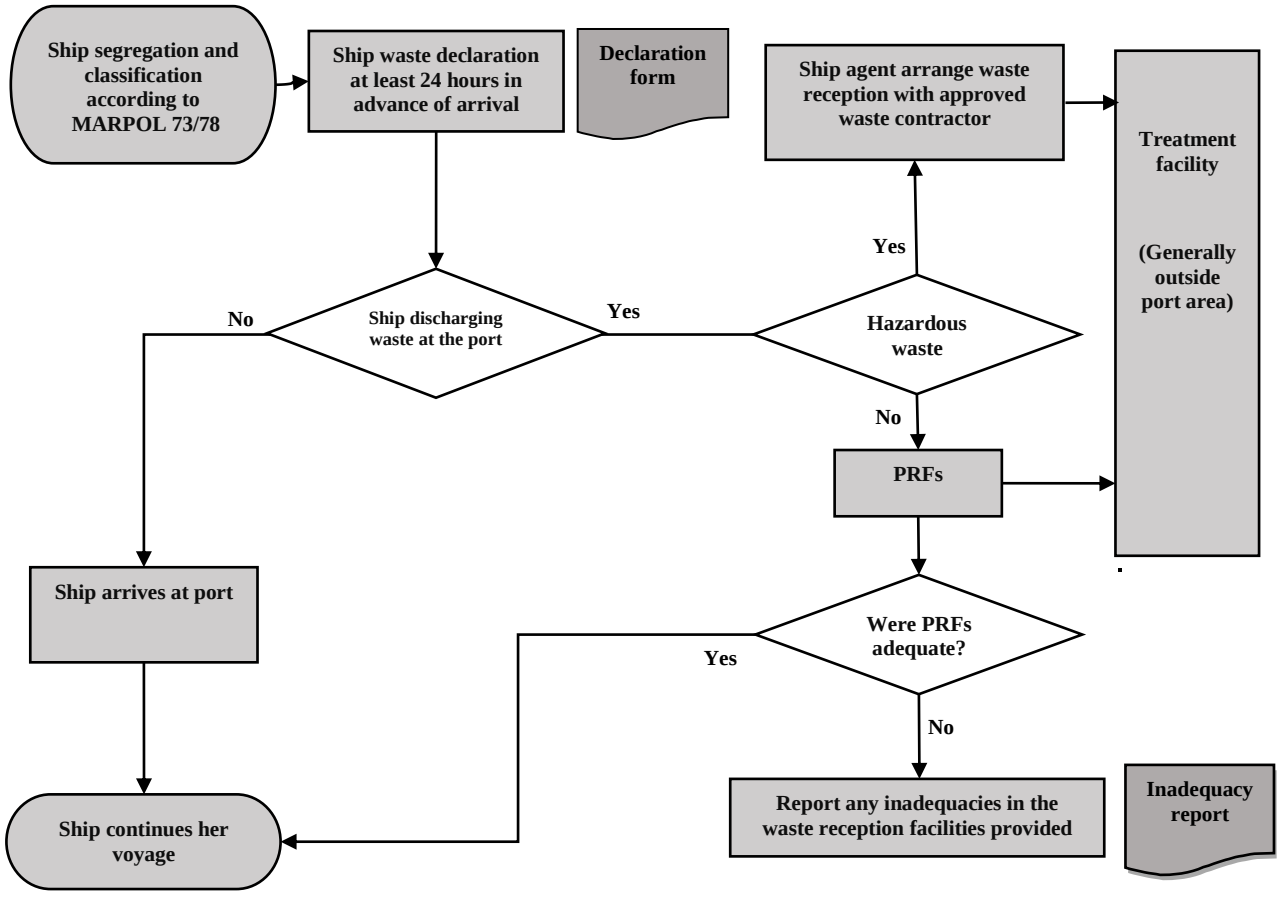

Figure 1. Waste management process flowchart

VIII. CONCLUSIONS

In summary this paper presents a comparative analysis of port waste management strategies, focusing on the examination of Port Waste Management Plans in four distinct ports. Through this comparative study, we aimed to gain insights into the diverse approaches employed by ports worldwide in managing maritime waste across four key aspects: the regulatory context, types of waste, infrastructure and facilities, and stakeholder involvement.

By examining the port waste management plans across various ports. We have developed a standardized process for effective waste management. Moreover, we identified common challenges facing ports in managing waste such as inadequacy of PRFs.

Through the lens of circular economy principles, this paper contributes to the body of knowledge on port waste management by providing valuable insights into the diverse strategies and challenges faced by ports in managing maritime waste. It is our hope that this research serves as a catalyst for further exploration and implementation of sustainable solutions within the maritime sector.

ACKNOWLEDGEMENTS

This work was supported by the Ministry of Higher Education, Scientific Research and Innovation, the Digital Development Agency (DDA) and the National Center for Scientific and Technical Research (CNRST) of Morocco, Alkhawarizmi/2020/35.

REFERENCES

[1] O. H. ¨Ozkaynak and G. T. ˙Içemer, "Based on stakeholder questionnaires of ship-derived waste, waste management re-planning in Ports and determining the need for inspection," Marine Policy, vol. 159, no. 105912, 2024.

[2] S. Zhang , J. Chen, Z. Wan, M. Yu, Y. Shu, Z. Tan and J. Liu, "Challenges and countermeasures for international ship waste management: IMO, China, United States, and EU," Ocean and Coastal Management, vol. 213, no. 105836, 2021.

[3] A. Dejaa, P. Weichbtothb and W. Śląc, "Sustainable Waste Management for Implementation of a Circular Economy Model in Port," Procedia Computer Science, vol. 255, p. 2654–2663, 2023.

[4] P. Evangelista, E. Sweeney, G. Ferruzzi and J. Carrasco, "Green Supply Chains Initiatives in Transport and Logistics Service Industry : An Exploratory Case Study Analysis,https://arrow.dit.ie/cgi/viewcontent.cgi?article=1064&context=nitlcon, 2010.

[5] A. Gupta, S. Gupta and R. Patil, "Environmental management plan for port and harbor projects," Clean Technologies and Environmental Policy, vol. 7, no. 2, p. 133–141, 2005.

[6] R. Darbra, A. Ronza, T. Stojanovic, C. Wooldridge and J. Casal, "A procedure for identifying significant environmental aspects in sea ports," Marine Pollution Bulletin, vol. 50, no. 8, p. 866–874, 2005.

[7] M. Puig, C. Wooldridge and R. Darbra, "Identification and selection of environmental performance indicators for sustainable port development," Marine pollution bulletin, vol. 81, no. 1, p. 124–130, 2014.

[8] C. Comtois and B. Slack, "Sustainable development and corporate strategies of the maritime industry," in International Workshop on Ports, Cities and Global Supply Chains, Hong Kong, 2007.

[9] I. Spadaro, F. Pirlone and S. Candia, "Waste management: new policies for EU port cities, ,," International Planning Studies, no. DOI: 10.1080/13563475.2021.1883421, 2021.

[10] P. Ulnikovic, M. Vukic and R. Nikolic, "Assessment of vessel-generated waste quantities on the inland waterways of the Republic of Serbia," Journal of Environmental Management, vol. 97, pp. 97-101, 2012.

[11] R. Mohee, D. Surroop, A. Mudhoo and B. Rughooputh, "Inventory of waste streams in an industrial port and planning for a port waste management system as per ISO14001," Ocean & Coastal Management, vol. 61, pp. 10-19, 2012.

[12] M. Puig, S. Azarkamand, C. Wooldridge, V. Sel'en and R. Darbra, "Insights on the environmental management system of the European port sector," Sci. Total Environ, vol. 806, no. 150550, 2022.

[13] L. Maglić, V. Frančića, D. Zeca and M. and David, "Ballast water sediment management in ports," Marine Pollution Bulletin, vol. 147, p. 237–244, 2019.

[14] M. R. H. Khondoker and K. R. Hasan, "WASTE MANAGEMENT OF A MARITIME PORT: THE CASE OF MONGLA PORT," Journal of Naval Architecture and Marine Engineering, 17(2020), vol. 17, no. 2070-8998, pp. 219-230, 2020.

[15] I. Ball, "Port waste reception facilities in UK ports," Marine Policy, vol. 23, no. 4-5, pp. 307-327, 1999.

[16] P. Van den dries, Guidance Document on Developing a Port Waste Management Plans, London: GLOLITTER PROJECT COORDINATION UNIT, 2022.