A systematic literature review on safety of methanol as a marine fuel

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1. Introduction

This paper summarizes the intermediate results of a literature review on safety and risk assessment at ports that store, handle, and provide methanol for ship refueling. This is the first review that attempts to cover the available standards organizations, international and regional organizations, IMO regulations, classification societies for the applicable rules and guidelines for assessing hazards and risk of the methanol storage at ports and during bunkering (refueling procedure at ships).

A further review is conducted on literature related to the safe use of methanol as an alternative marine fuel, together with risk assessment studies performed in the last 10 years. The aim of this review is to investigate scientific and harmonization gaps of methanol bunkering safety within the EU.

2. Methods

The review covered scientific literature, standards, regulations, white papers, guidelines and examples of best practices. During the reviewer process, the following parameters were considered:

* Information sources: citation databases (Web of Science, Scopus), registers, websites of international organizations (IMO, IAPH, SGMF, IMPCA, MI), classification societies (ISO, DIN, DNV, ABS, BV, Lloyds), regulators national/multi-national (EU, EMSA, UN).
* Main keyword: methanol.
* The language of publications was limited to English.
* Search context limitations: a.) safety/process safety; b.) maritime or bunkering; c.) fuel; d.) storage; e.) operational procedures.

Search hits were compiled and examined each one in a detail for the applicability of the context limitations.

3. Results and discussion

The review identified 184 scientific papers (combined results from Scopus and Web of Science). The 184 papers were reviewed in two steps. First, papers were briefly reviewed, focusing on the title, keywords, and abstract. Papers that, for example, only indirectly addressed safety or methanol were excluded. In the second step, the remaining papers were manually reviewed, focusing on how the use of methanol was explored (focusing on safety, environmental and economic aspects) and in which context (focusing on the maritime application, specifically on the use of methanol in ports). The papers that, for example, focused on the life cycle assessment of alternative fuels and only briefly mentioned the use of methanol in ports or bunkering processes were excluded. The review process highlighted 12 papers. The papers explored methanol as an alternative marine fuel from both environmental and economic perspective (e.g., Deniz & Zincir, 2016; Jesus et al., 2024), evaluated the readiness to bunker alternative marine fuels (Wei et al., 2023), discussed how to assure their availability (Kloppot et al., 2023), provided decision support system for bunkering operations (Sheng, 2024), developed training scenarios for safe bunkering (Liu, et al., 2024), and addressed the views of various stakeholders on bunkering operations (Kolakowski et al., 2024).

The review of standards, regulations, white papers, guidelines and examples of best practices identified 51 documents, contents of which are discussed as follows:

The Methanol Institute, IMPCA and ISO documents cover the quality and safe handling aspects of the methanol as a maritime fuel (Methanol Institute, 2020; IMPCA, 2021; ISO, 2024).

Regarding the design and operation of the methanol fueled ships, there is a plethora of documents at various organizations, which can be summarized to the interim IMO's guidelines (IMO, 2020) based on the IGF requirements for low flashpoint fuels (IMO, 2015). The guidelines cover the methanol/ethanol use, e.g., ship design and arrangement, fuel containment system, material and general pipe design, bunkering, fuel supply to consumers, power generation incl. propulsion, fire safety, explosion prevention and area classification, ventilation, electrical installations, control, monitoring and safety systems, operation.

The classification societies adapted the IMO guidelines and published more specific rules and regulations on the ships using methanol or ethanol for propulsion (ABS, 2024a; ABS, 2024b; BV, 2024; Lloyds, 2024a; Lloyds, 2024b). While those rules and regulations cover also the bunkering, the bunkering procedure, requirements, safety measures are prescribed in addition in a form of detailed checklists by the classification societies (Lloyds, 2020) and specific regulators and ports/associations (EMSA, 2023; IAPH, 2023; SGMF, 2024; Port of Gothenburg, 2022). DNV prepared also a competence requirements reference (DNV, 2024).

Regarding the specific national legislation, we did not find anything.

At the specific port level, we found two risk assessment reports, both related to the Amsterdam and external safety of the bunkering operations (DNV, 2021; AVIV, 2023). Both reports are interesting as they cover different bunkering modes and different fuels (LNG, methanol, ammonia, hydrogen and their operational combinations).

In addition, we found that within the GreenVoyage 2050 project[[1]](#footnote-2) a regulatory mapping exercise was prepared. Regarding the methanol mainly high regulatory readiness was assigned, but low readiness regarding the potential marine pollution and human health hazards. As the web site mentions marine standards in progress that are today (end of 2024) already available, the gap analysis seems a bit outdated in mentioned details.

4. Conclusions

The use of methanol as a maritime fuel appears to be covered by the IMO regulations and other international organizations, classification societies and port authorities, however, there is no specific national legislation within the ADRION countries.

There is also a scarcity of papers in the scientific literature that would holistically address all the aspects (e.g., safety, environmental, and economic) of using methanol as a marine fuel in ports. A more in-depth analysis is needed to address the research landscape further, highlight potential gaps in the literature and explore how the research on the use of methanol as a marine field is developing compared to research on other alternative fuels.

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1. <https://greenvoyage2050.imo.org/alternative-marine-fuels-regulatory-mapping/> (accessed 18.11.2024) [↑](#footnote-ref-2)