

# Assessment of Factors Contributing to the Risks of Cargo Liquefaction Accident in Bulk Carriers (A Qualitative Approach)

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**ABSTRACT:** Liquidation of cargo in bulk carrier has been identifying as a major hazard affecting the bulk carrier shipping and has resulted to several loss of lives. This study assesses the liquidation problem in bulk carrier shipping, it also discusses the mechanisms by which cargo liquefaction occurs in bulk carrier and the factors influencing the risks of occurrence, based on a qualitative approach. Based on the findings and survey, the unsafe storage condition, poor compliance with the testing and certification of cargoes, poor loading plan, have been identify as some of the root casual factors influencing the risk of liquidation problem in bulk carrier. This study will contribute to increasing the awareness and understanding of the problem of cargo liquefaction and will facilitate the development of regulations that reflects the realities of this problem and assist in the development of future recommendations for mitigation plans against the liquidation problem in bulk carrier.

## 1 INTRODUCTION

Liquefaction of cargo is a phenomenon, where a soil-like material is abruptly transformed from a solid dry state to an almost fluid state and this problem has been identifying as one of the deadliest and major cause of marine casualties in bulk carriers, often associated with tragic loose and fatalities. Accidents attributed to cargo liquefaction, mainly results in loss of stability and subsequently the capsizing of the ship [4]. The probability of liquidation of cargo in a bulk carrier vessel, often constitute a wide range of interaction of several contributing actions, which often result to a complex risk environment that increases the chances of occurrence [8]. There has been an increasing concern over the losses of bulk carriers' vessels, in recent time with the high fatality rate of seafarer, and numerous regulatory efforts like the IMSBC code by IMO has been made, but incidents suspectedly to be caused by liquefaction continues to occur with higher fatality rate [10]. The continuous

occurrence of this incidents leads us to question whether the identified known causes are properly reflected and addressed by the maritime industry. A causal factor can be defined as any major unplanned, unintended contributor to an incident that if eliminated would have either prevented the occurrence of the incident or reduced its severity or frequency. Looking at the literature survey, several researchers had focused on numerical evaluations and experiments to reveal the liquefaction potential based on the characteristics of the cargo, but limited study had been made on the actual cause of this problem. Hence, to fill the literature gap, this study has a significant interest in identifying the root causal factors of liquefaction incidents, as this will necessitates the understanding of the interaction of events through a chronological chain of activity leading to the liquefaction incidents [5–7, 9, 11].

## 2 THE PURPOSE OF THE STUDY

These studies assess the problem of cargo liquefaction to understand the combination of causal factors leading to the incidence. The study is aimed at uncovering the problem of liquidation of cargo in bulk carrier and to increasing its awareness by looking at the parameters influencing the risks of occurrence. Finally, some recommendations are presented for possibly preventing future occurrence.

## 3 MATERIAL AND METHOD

The study investigated the liquidation incidence using information gathered from reviews of published articles of incidence caused by liquification and Interviews with expert and professionals in the industry.

Name	Position	Date
1 Andrew Moore & Associates Ltd (Singapore)	Consultancy & Survey	June 2021
2 Rio Tuba Nickel Mining Corporation (Philippine)	Operations worker	July 2021
3 San Roque Metals Incorporated (SRMI) (Philippine)	Operations worker	July 2021

Because of all interviewed staff do not want to disclose their names, the table do not include name of the participants. The outcome of the information gathered has been utilized to give a clear picture of the problem of cargo liquefaction for understanding the contributing factors influencing the risks of liquidation of cargo.

## 4 PROCESS OF LIQUEFACTION

Liquefaction is a phenomenon in which a soil-like material cargos are abruptly transformed from a solid dry state to an almost fluid state. As larger particles generally cannot retain much water and will settle together with greater voids space between them, while smaller particles will retain more water because of their greater contact and increased surface, so during the voyage of such cargo in an open seaway, particularly during heavy weather condition, these cargos are often subject to agitation due to the vibration of the engine, ship's rolling, and pitching impacts and the resultant effect will force the rearrangement of the cargo particle as they are being subjected to significant stresses.

The resulting effect is the compaction of the inter-granular spaces, and the removal of interstitial air, and this will lead to an increasing pores water pressure, thereby forcing the cargo solid particles to be separated from its moisture content as (Fig 4). The cargoes with high moisture content lose its shear strength due to the loose of direct contact between their particles and they become prone to sliding, particularly when the cargo is shallow and subject to large heel angles. These conditions will make the cargo material to behave like a liquid and in the

resulting viscous fluid state cargo may flow to one side of the ship with a roll but not completely returning with a roll to the other way [1]. Liquefaction often starts in a small portion of the cargo and rapidly spreading throughout the entire cargo, resulting in a sudden shifting of the entire mass and the ship may be affected, progressively reaching a heavy list and loss of control, which could result in the vessel capsizing and sinking in the worst-case scenario due to lack of stability.

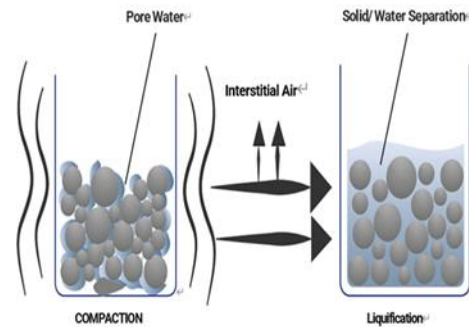


Figure 1. Compaction and subsequent liquefaction

### 4.1 Cargo prone to liquefaction

Liquefaction may occur in the cargoes categorized in Group A of the Code of safe practice for solid bulk Cargoes (BC Code) such as iron ore fines, nickel ore, coal, particularly when they are loaded in condition where their moisture content exceeds the transportation moisture limit value of the cargo [2, 3].

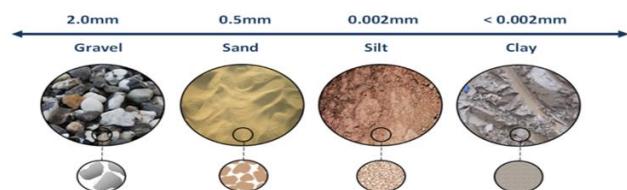


Figure 2. Variation in particle sizes of ores

The granular cargo materials are often consisting of varying particle sizes and may contain water within them, which were accumulated during mining process of the cargo or during storing them on grounds that are exposed to weather while awaiting loading. These cargo materials have the characteristic of cohesion, and may liquefy during voyage, even if they are cohesive and trimmed levelly. Most of the popular cargo materials involve in this incident are briefly outline below.

#### 4.1.1 Nickel ore

The largest exporters of nickel ore are Indonesia and the Philippines, and these ores are extremely low-grade ore, with nickel content as low as 1% and the remaining 99% are fine grained, almost like mud with traces of nickel ore. Nickel ore are often dug from open pit mines, hence exposing the fine-grained nickel ore to wet weather, and increasing their moisture content and are arguably the most dangerous of all

bulk cargoes, suspectedly to have claimed the highest number of fatalities.

#### 4.1.2 Iron ore fine

Iron ore fine have been associated with several liquefaction accidents. These are iron ore with larger proportion of smaller particles and may liquefy if their moisture content exceeds their TML. The open mining and storing of the iron ore fine in certain milling sites prior to loading increase the moisture content.

#### 4.1.3 Bauxite

Bauxite, which consists of oxide type ores containing hydrated alumina is mainly used to produce aluminum. The largest exporters of bauxite ore are Australia and guinea They are mined in open pit mines, then converted to alumina (aluminum oxide), which are further processed to pure aluminum by electrolysis.

## 5 RESEARCH FINDINGS

Based on the expert consultation and study of the available report of incidence suspectedly caused by liquification of cargo, several actions were identified to influence the risks of the liquefaction incidence. Although, the errors resulting from these actions are independent from one another, but human factor is the basis of all of them. Below illustrate the key findings and problem areas.

### 1. Lack of proper cargo inspection

The cargo is usually stockpiled and transferred in open barges and trucks and in the event of poor climate or raining weather, the moisture content can be increased, creating more chances for cargo liquefaction. Also, the tropical climatic condition has a higher moisture content that can be absorbed by the stockpile's cargoes of fine-grained minerals prior to loading, as it has a higher moisture content that can be absorbed by the stockpile's cargo prior to loading.

### 2. Non-implementation of rules

The neglect for regulation is the main causal factors in most liquefaction incidence. The International Convention for the Safety of Life at Sea, 1974 and its Protocol of 1988, Chapter VI (Carriage of Cargoes) (Regulation 1, 2, 7 and 4) have provided rules and standards for the safe transportation of solid bulk cargoes. The duties of all concerned supervising parties, from the submission of information on cargo, the proper stowage and down to the shipper's duty to submit information about cargo to the master were stated. Also, where the requirement to load and trim bulk cargoes to a reasonable level, as necessitated by the boundaries of the cargo space, to minimize the risk of shifting and to maintain adequate stability. But, despite the provisions of code, majority of the milling yard located in developing countries, had always neglect the provision.

### 3. Poor knowledge of cargo

The wrongly categorization of iron ore fine as

normal iron ore, which according to the IMSBC Code, are cargo that poses no liquefaction risk are linked to most liquefaction accidents. Also, the wrong labeling of cargo in the IMBSC code such as bauxite, whose material behavior are not well understood, may increase the risk of cargo liquefaction as most workers are ignorant of their characteristic's behavior. Although, bauxite is listed under Group C cargo in the IMSBC Code, meaning that it poses neither chemical nor liquefaction risks, but they sometimes behave like Group A due to their material behavior. Their listing in the Group C only covers relatively dry and relatively coarse-grained bauxite but if the bauxite has a large proportion of powder, or if the moisture content is above 10%, the cargo is potentially unsafe and behave like Group A.

### 4. Lack of functional equipments

This problem is related to poor tmt testing materials resulting to incorrect result are the main causal factor. The lacks proper equipped facility to perform the necessary testing required for preventing cargo liquefaction. lacks proper equipped and facility for performing the necessary TML test which is required to prevent cargo liquefaction. The procedures for testing the moisture content by IMO were generated for concentrates ore and not for fine ore, and in this case testing methods for calculating the transportable moisture limit of the cargo can be characterized as inadequate and often result to a wrong result.

### 5. Problem of working condition

The practices like the open storage of the ore material prior loading, especially in the humid climate can contribute to increasing the moisture content of the cargo. Also, most of the mines are in very remote areas, and often engage in an improper loading condition of which makes TML testing difficulty and the locations of the ports where these materials are loaded When any of these types of cargoes is to be transported by sea in a solid bulk state, the TML should be determined. For a general cargo vessel, each of these cargoes must be loaded for transportation only when the Moisture Content of the cargo is lower than TML

## 6 DISCUSSION

The continuous efforts towards safeguarding against liquefaction problem in bulk carrier has led to the implementation of the IMSBC Code. The IMSBC Code introduces the upper bound of moisture content of cargo called the Transportable Moisture Limit (TML). The TML is defined as 90% of the Flow Moisture Content (FMP), which depends on the characteristics of cargo and should be measured experimentally. However, the objective of this code has not been fully achieved as certain human negligence resulting to the poor enforcement of the regulation continue to occur. The IMSBC Code's stated the application requirements and oblige the shippers to test and declare the properties and moisture content of the cargo, verification of the vessel's safety was to be confirmed by the tripartite agreement of the Port State of the exporting country, Port State of the receiving

country and Flag State of the vessel and the master of the vessels was confirmed all test result and ensure the proper loading and monitoring of the vessel. But unfortunately, based on available report of cargo liquidation incidents and the interview from experts involved in the industry, there has been failure in most of the operation activities leading to the risks of accident. It is evident from recent accident statistics that most of the accident relating to liquefaction like the Emerald Star (2017), the Nur Allya (2019) occurs in developing countries, particularly in southeast Asia of Indonesia and Philippines and are attributed to improper human actions and wrong TML testing result of the cargo. These contributing factors which include human actions negligence like the poor compliance with the testing certification of cargoes, unsafe storage condition, insufficient loading plan and lack of proper monitoring from relevant parties, has been identify as some of the factors increasing the risks of liquidation and can be seen as a major legislative gap in the implementation of provision of the code.

## 7 CONCLUSION

The present study discusses the problem of cargo liquefaction in bulk carrier and assess the contributing factors influencing the continuous occurrence of this problem. Although, several efforts have been made to manage this problem, but accident suspected caused by cargo liquefaction continue to occur, but human errors, operation errors and regulation negligence during the loading and testing operation are the contributing factors to liquefaction of cargo incident. It may be concluded that there are several contributing factors influencing the continuous occurrence of this problem is can be traced to poor operation human negligence. The successful prevention of this problem will be achieved when proper measures are taken before cargo loading operation, during loading process, at the completion of loading and during the voyage of the vessel which will all depend on the cooperation of relevant parties involve doing their job efficiently.

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