J. Res. Technol. Eng. 3 (1) , 2022, 37-46

Journal Of Research Technology & Engineering
www.jrte.org

The hazard identification and risk analysis systems for marine environment

M.B.D.K. Siriwardena*, Subasinghe N.T.S.

Faculty of Technology, University of Sri Jayewardenepura
*mbdksiriwardena@gmail.com,

Received:01 Dec 2021; Revised: 25 Dec 2021; Accepted: 09 Jan 2022; Available online: 10 Jan 2022

Abstract: Shipping accidents are unforeseeable events that cause financial loss, property damage, marine environmental pollution, and the death or injury of people. Human error, technical failures, natural conditions, shipping factors, route conditions, and cargo-related factors are all factors that contribute to these incidents. When wildfires and bombings destroy the marine environment in a matter of minutes on land, events like oil spills put our seas and oceans in jeopardy in a matter of minutes. Unfortunately, maritime accidents are unavoidable, despite creative and innovative technologies in the shipping sector and strict adherence to safety rules and regulations. This paper discusses marine accidents and how those affect the marine environment with prevention protocols.

Index Terms: Maritime, Protocol, Shipwrecks, Spillage, Venture

1. INTRODUCTION

Marine incidents refer to unfavourable maritime events such as accidents and near-misses. An accident is an unintended event that results in harm, death, economic loss, environmental damage, or property damage or loss. An accident is a one-of-a-kind collection of circumstances or events, even though the terms accident and incident have different meanings. Fig 01 represents the X-Press Pearl ship incident in Sri Lanka in 2021, and It was one of the leading marine incidents in Sri Lanka [1].

Fig. 1. X-Press Pearl ship incident in Sri Lanka [1]

Shipping accidents have a variety of effects on the marine environment. Not only do accidents and collisions cause marine pollution, but human errors such as oil spillage, solid waste, oil transferring, and bunkering can also result in marine pollution. Otherwise, a significant shipping accident becomes even more critical due to water ingress, which may worsen the ship's damage is exacerbated by heavy weather or

strong current. However, in some other accidents, oil spillage makes the problem more to coastal and marine environments. As a result, statistics on maritime accidents and marine pollution, both caused by human error, were examined in this study.

2. INCIDENTS FROM SHIPPING ON MARINE ENVIRONMENT

Recently, some statistical research has identified human error as the primary factor in most marine accidents. In ship-related marine environment cases, there are many ways of ship-generated pollution types according to International Maritime Organization's 2012 Report named International Shipping Facts and Figures Information Resources on Trade, Safety, Security, and Environment [2].

2.1 Crude Oil Tankers Accidents and Oil spills from ships

Almost every error that we make negatively impacts the planet's environment and species. While some human errors have long-term environmental consequences, only a few have immediate and massive consequences, resulting in the extinction of 1000 of species in some cases. On land, wildfires and bombings destroy the marine environment in minutes; on the seas and oceans, oil spills put our seas and oceans in jeopardy in minutes. Oil spill disasters have long been a significant source of concern in the marine world. They are both commercial and environmental catastrophes. As a result of an accident involving cargo ships or oil transporting tank shops, the ocean water became contaminated with liquid petroleum hydrocarbon, causing long-term environmental damage [2,3]. Oil spills harm beaches, wildlife habitats and kill fish, marine mammals, and birds, among other things. When oil reaches the coast, it affects human settlements, mangrove forests, and other natural areas. In a nutshell, an oil spill causes long-term disruption to an entire ecosystem. While major spills get the most attention, several more minor and more common incidents occur regularly. Fig. 2 represents the oil tank ship fire time that happened in the Sri Lankan sea area.

Fig. 2. Oil tanker fire in Sri Lankan Ocean area [4]

On the other hand, over one million metric tons of petroleum enter the marine environment from municipal and industrial sources and marine transportation, natural oil seeps, and accidental oil spills. The International Maritime Organization's measures have helped ensure that most oil tankers are built and operated safely. They are designed to minimize the amount of oil spilt in the event of an accident. Routine tank cleaning operations have also resulted in less operational pollution. Despite the occasional major accident, which can cause a spike in annual statistics, the overall trend shows that both the number of oil spills and the amount of oil spilt each year are improving. The most significant decade-to-decade reduction in oil spills occurred from the 1970s to the 1980s. The adoption and entry coincide into force of the International Convention for the Prevention of Pollution from Ships. In 1973, it was modified by the MARPOL Protocol of 1978 [5].

2.2 Cruise Vessel Accidents/Mishaps

The cruise industry has no bearing on the shipping industry. Despite being a small part of the industry,

Cruise ships are a significant source of pollution in oceanic and marine areas, similar to commercial vessels. The cruise ship experience as a form of recreation is a relatively new phenomenon. Passenger ocean liners ceased operations in 1986 due to the dominance of passenger air transportation. Cunard Lines, however, saw a niche market that could be exploited starting in 1986, where passengers would prefer ocean cruising as a form of recreation. In the 20 years since then, cruising has proven to be one of the most popular vacation activities [6].

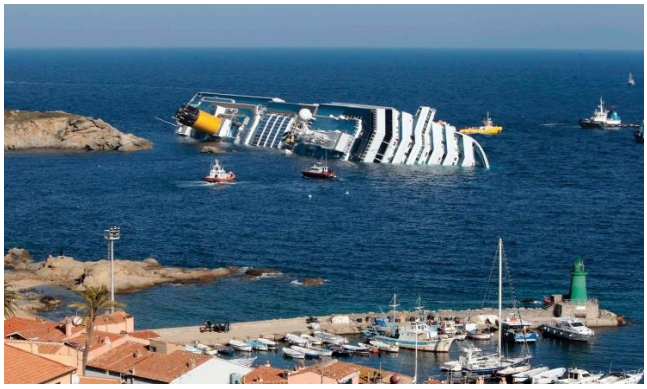

Fig. 3. Costa Concordia disaster [7]

The cruise industry alone generated more than $42 billion in total economic activity in the United States, supporting over 356,000 jobs Cruise Line International Association (CLIA). So, it increased 75 % over five years. As a result, cruise shipping also increased, and mishaps also increased. Several high-profile cruise line disasters or accidents have occurred in recent years. It represents Fig. 3. With the 2012 Costa Concordia disaster and the subsequent Carnival Triumph incident, concerns about cruise line safety are surfacing. The ship collided in the case of the Costa Concordia, causing the ship to roll over and killing 32 passengers. Three thousand one hundred forty-three passengers were stranded in the Gulf of Mexico for days after the Carnival Triumph lost electrical power because of an engine room fire [6]. So, as a result of that incidents, ships are sink, and those hazardous materials of the ship are added to the marine environments and finally, its case to pollute environments with dangerous conditions.

2.3 Commercial Fishing Mishaps

Commercial fishing has a well-deserved reputation for being a dangerous and challenging business. Commercial fishing vessels usually operate in a 200-mile economic zone off the coast. The term "commercial fishing" encompasses a wide range of vessel configurations and sizes. However, these vessels are decked, have enclosed areas, and carry out industrial-scale fishing operations. Commercial fishing vessels can range from small boats to massive "factory" ships. Over 40,000 of the 4 million fishing boats globally are over 100 tons. Commercial fishing vessels and their operations are hazardous to work environments due to their size, complexity, and operational range. Every year, 42 commercial fishermen die as a result of their work [8].

Commercial fishing vessels are frequently exposed to harsh and challenging conditions. When a fishing boat is involved in an accident or incident, medical help may be hours or even days away. That's why it regulates all commercial fishing operations in each country. Recommends that all crews be trained in Cardiopulmonary resuscitation (CPR) and first aid. Some of the most common commercial fishing vessel accidents are as follows:

- **Sinking**

  Catastrophic hull compromises cause a third of all injuries on commercial fishing boats. This is due to large waves, which can sometimes capsize the ship. When a fishing vessel's hull is sufficiently damaged, it can sink quickly, endangering the lives of all seamen on board.

- **Mechanical or factory accidents**
  Many fishing vessels have complex, below deck factories that aid in preparing seafood for the market. Accidents here frequently result in limb amputations or crushing injuries. Factory setups that are dangerous on land are even more difficult at sea, necessitating additional safety precautions.
- **Environmental accidents**
  Fishing boats are categorized by their very nature. Small spaces can quickly become toxic due to a lack of oxygen or hazardous materials stored there. Hypoxia or brain injury can result from accidents involving these small spaces.
- **Slips and falls**
  Falls overboard account for nearly half of all commercial fishing fatalities. Commercial fishers can slip and fall due to a slick deck and constantly shifting vessels, not to mention long shifts and challenging work. Once overboard, the primary safety concerns are drowning and hypothermia, so crew members must be rescued quickly to avoid severe injuries and save their lives.
- **Fishing accidents**
  Commercial fishing necessitates specialized equipment, which varies depending on the type of fishing activity that a vessel is primarily tasked with. However, any fishing equipment can result in an accident on the deck.

2.4 Cargo Hauling and Barges Accidents

Cargo ship accidents happen all the time, despite everyone's best efforts and intentions. Whether in port/at sea, Cargo ships can be a dangerous place to work. Many seamen and maritime workers have been injured in cargo ship accidents, and the attorneys at Montagna Maritime Law have worked with them [9]. Cargo ships, also known as container ships, transport most goods between continents. The ships themselves are among the significant ever built, and they sail in nearly every kind of weather. The ships are usually loaded with a large amount of cargo, which must be appropriately secured. As a result, cargo ship collisions can quickly escalate from minor to fatal. Cargo ships have a largest amount of mass, both in the containers they carry and the displacement of the vessels themselves. It means that everything on a cargo ship is large and powerful. The types of accidents that occur on cargo ships are usually a result, at least in some way, of that size and power. Common types of accidents in below,

- **Cargo transport accidents**
  Transporting and Stacking cargo containers must be done safely and stably. Best practices varying and safety guidelines can result in accidents and injuries. A typical container can weigh several tons, posing a danger to both ship and crew when improperly secured, leading to containers falling over.
- **Accidents involving machinery**
  Cargo ships usually on powerful machinery to complete basic tasks. Machinery breakdowns can be dangerous and cause accidents, especially when maintenance or safety guidelines are not followed from engines to cranes.
- **Slips and falls**
  It should sound mundane. but a slip and fall on a cargo ship can have dire consequences. A seaman could fall overboard in the worst cases, a life-threatening situation.
- **Collisions**
  In 2017, 2 high profiles collisions occurred between container ships and U.S. Navy destroyers. Collisions at sea happen, and they can occur in port, as well. Any crash involving a cargo ship can have disastrous consequences due to the sheer mass of the vessels involved.

Fig. 4. X-Press Pearl incident in Sri Lanka [10]

For example, the main Sri Lanka marine incident of the X-Press Pearl that three-month-old, ship carrying 25 tons of nitric acid caught fire off. Sri Lankan aircraft and navy vessels were dispatched to assist in the firefighting effort (Fig. 4). At least eight containers, some of which are suspected of containing acid, have sunk into the sea, prompting authorities to issue swimming bans in the area. The vessel is now in such bad shape that moving it 50 nautical miles away from the shoreline is underway [11]. The flames are being fanned even more by the strong winds in the area.

3. POTENTIAL IMPACTS AND HAZARDS

A hazard is a source that can cause harm or adverse health effects to a person or persons. Risk is one of the most relevant terms when referring to hazards to minimize the impact of shipping on the marine environment. A closer look at the marine environment reveals several potential effects on the marine environment. From this, there is a need in the present times to pay special attention to the dangers posed by shipping. The potential hazards to the marine environment can be categorized into two types:

- Potential hazards to the marine environment caused by shipping.
- Risk to the marine environment from accidents during shipping.

It will be clear from the above section that there are several accidents caused by shipping. But here, we discuss the possible hazards of such accidents.

3.1 Physical disturbances

Physical disturbances are interactions that occur at sea between ships and animals. In contrast to the two-dimensional terrestrial environment, the ocean route, which requires most land animals to cross the road directly, increasing the risk of crashes, is a three-dimensional habitat that allows people to dive without being attacked. Shipwrecks and transportation, however, have an impact on the maritime ecosystem. A wreck results from an unintended contact in the sea environment that can result in deadly or significant trauma or injury [12].

The addition of waste by ships to the marine ecosystem will negatively affect the marine ecosystem and terrestrial life. Ships generate a lot of garbage, which puts a lot of strain on the maritime environment. For ports and ship-owners, a lack of suitable facilities for receiving ship-generated rubbish is a big issue [3].

In addition to the dangers posed by shipping and shipwreck, the threat posed by a wreck in the ocean and the addition of its cargo to the ocean system is enormous. This can be described as a significant hazard that affects marine and terrestrial life.

3.2 Chemical pollution

The direct and indirect input of chemical wastes created by shipping to the ocean is marine chemical pollution. Furthermore, oil spills have a direct impact on maritime vessel pollution. Examples are offshore

oil tanker accidents and crude oil tanker and cargo ship accidents. Or, more subtly, call attention to the pollution caused by ship exhaust emissions. Due to the spread of landfills to previously unaffected locations, oil spills into the oceans pose a significant threat to marine ecosystems. It can be transferred beyond the sea and onto adjacent places, posing several significant risks. Many killer whales died after being exposed to the 1989 Exxon Valdez oil disaster, possibly due to inhalation of fumes or oils, oil contact with the skin, and eating of polluted prey. The population's subsequent originality was low [12].

3.3 Air pollution

It can be pointed out that the amount of air pollutants released into the environment during shipping and ship accident is very high. Air pollutants emitted during a ship's voyage can cause adverse effects such as global warming and disruption of living organisms, a significant factor affecting the entire environment. When a fire breaks out again in the ocean, all the cargo on board is ignited. The temperature emitted by it causes the surrounding ambient temperature to rise, further polluting the ambient air. The on-May 2021 X-Press Pearl fire in Sri Lankan waters is a case in point.

3.4 Underwater noise pollution

Background noise in the world oceans at a low frequency (i.e., 5-500Hz). Fish and other marine organisms are greatly affected by underwater noise. Transport via sea Submarine noise is a significant source of pollution. Explosions in shipwrecks also contribute to underwater noise pollution. Ships have a positive impact on the environment. Due to spatial and temporal differences, underwater noise levels across vast geographic areas and individual vessel noise are frequently indistinguishable. Even across long distances, aquatic noise pollution substantially impacts marine life. It can also significantly negatively impact short-term noise pollution, such as undersea noise [3].

4. RISK ASSESSMENT TO REDUCE INCIDENT HAZARDS

Unwanted ocean events are referred to as "ocean events." An accident is an unintended event with negative repercussions—for instance, injuries, death, economic loss, environmental loss, and property loss or damage. Accidents occur because of an unexpected event. On the other hand, shipping is the international trade's wholesale delivery system. It also has a significant impact on humanity's collective well-being. Modern technology has not prevented shipping mishaps, and they continue to occur today. The following are some of the reasons behind shipwrecks [3].

- Natural occurrences such as strong winds and high tides are examples of natural conditions.
- The ship has some technical flaws.
- Errors in shipping due to poor road conditions.
- Human error causes accidents.
- Cargo-related accidents (Weights and dangerous objects are included).

Offshore oil rig mishaps, crude oil tankers and cargo ships accidents, cruise ship mishaps, commercial fishing mishaps, and cargo hauling, and barge accidents are among the naval incidents listed previously in the article. The proposed methodology for minimizing those marine and maritime hazards generally shows that risk assessment consists of the following stages [13]. Fig. 5 represents the technique for determining risk is better illustrated in the order of flow sequences shown below [14].

Fig. 5. The risk assessment procedure [14]

4.1 Identification of hazards.

Things or situations have the potential to inflict harm. Hazard identification at sea is the first step in identifying whether or not a given scenario, piece of equipment, or another aspect of a maritime mishap has been harmed. This is something that must occur prior to an accident occurring. Before a shipwreck, high-risk offshore oil tanker accidents, crude oil tankers, and cargo should have been identified in advance of their potential risk of an oil spill. In addition, all conditions impacting vessel accidents, commercial fishing accidents, freight, and barge accidents should be determined ahead of time. Hazards are more likely to be found in the following areas [14]:

- The physical working environment
- The equipment, materials, or substances that were utilized,
- Work tasks, how they are carried out,
- Work planning and management

As recommended considerations for identifying dangers, it can point to previous events or accidents, learn about security concerns, inspect workplaces, review functions and processes, and define safety safeguards to assess if an event or disaster is impending.

4.2 Those hazards assessments of the risks association.

In the second stage, the risk assessment related to those hazards is done, and the application used to describe the whole process is the risk assessment. Risk should be assessed primarily on the threat, which is a correction between dangers and hazards. Risk assessment should be done on various aspects such as risk to ecosystems, animal and human lives, and the economy. It is critical to understand the risk assessment's severity, the scope of existing control measures, the procedures to be followed to control the risk, and whether immediate action should be taken to evaluate the risk assessment [14]. The factors that must be included in a risk assessment are as follows.

- Identify things that may contribute to a risk

- Review of acceptable health and safety information
- Assessing the magnitude of the hazard
- Evaluate how a threat can cause harm
- The probability of damage is determined in advance
- Identify measures to eliminate or control the hazard.
- Records to be kept ensuring risk elimination or control
- Reasonable range of conditions, the risk assessment process is carried out by reviewing any available information about the accident.

4.3 Identification of ways of managing the risks identified.

Identification is identifying ways to manage risk. Grants are intended to determine the appropriate means of eliminating a hazard or to control the risk when another danger cannot be stopped. One aspect here is risk management. All hazards must be addressed before people are injured, become ill, or damage to plant, property or the environment occurs once the hazards in marine transportation have been identified, their risks assessed, and the review of the existing control. It should take place after a risk assessment in the marine environment, and management was able to find the trouble.

Risk management in the workplace necessitates, in the first instance, the elimination of risks to the greatest extent possible. If complete eradication is not achievable, dangers should be minimized to the greatest extent possible. All threats that have been identified should be addressed in order of importance [14].

4.4 Cost-benefit assessments of the options.

The cost-benefit assessment of alternatives also involves a cost assessment of the required and required resource contributions for the actions taken in the risk management and, therefore, the environment needed to deal with the risk successfully. The other aspect of this is to assess the benefits of avoiding the hazard. It helps a lot to prevent dangers and thereby sets the value of the threats.

4.5 Making decisions on which options to select.

The final stage of the risk analysis system is to decide the options to be selected. In the process of identifying the hazard, all the options available for mitigation are considered based on the factors that have developed in the process, and the most appropriate alternatives are selected, avoiding the shortcomings of those alternatives. Choosing the most suitable option is the best answer to the risk, and there are all the benefits needed to minimize the risk.

5. HAZARD PREVENTION METHODS IN THE SHIPPING

Shipping is regarded as a secure, cost-effective, and environmentally friendly mode of commercial transportation. Over the last decade, the shipping industry has taken several steps to improve its level of safety. The principal underlying shipping regulations are harmonized national rules based on International Maritime Organization (IMO) conventions and resolutions. Despite this progress, shipping accidents, particularly collisions, continue to be a significant source of concern. Accidents have many consequences, from minor injuries to fatalities and little to severe environmental and property damage. Humans, the marine environment, properties, and activities aboard ships and ashore are all adversely affected in various ways and to varying degrees by maritime accidents.

It would be a massive accomplishment if it were feasible to conserve the marine ecosystem and reduce other negative consequences by preventing shipwrecks at sea. Crew errors at sea mainly cause wrecks. The

ship's crew is well-trained there, and the potential hazard can be reduced by hiring employees who can react more appropriately in the event of an accident on board.

Non-compliance with maritime safety laws is another aspect that emerges when analyzing the hazards and techniques in the marine environment. It is worth noting that beginning aquatic activities in line with global marine protection regulations will reduce maritime accidents to a bare minimum. Legalizing following modern standards is also necessary.

Many maritime mishaps can be avoided by having the ship's entire quality assessed before starting any voyage. It can tolerate a lot of bad weather if it's adequately protected.

7 CONCLUSION

The marine environment is harmed not only by shipping accidents, collisions, and oil spills, but also by ship bilge water, ballast water, and solid waste discharged into the sea, all of which pose environmental risks and result in irreversible marine pollution. Shipping accidents have become increasingly environmental problem in recent years, with the consequences being critical for all parties in terms of human lives, the marine environment, trade, and financial losses. As a result, many regulations relating to pollution and accidents have been enacted to improve the human life safety, property, and the environment by reducing the number of casualties, incidents, and collisions. As stated in this study, IMO (2012) reports reveal that ship-generated pollution continues to pose a threat to the marine environment. Even though pollution-related regulations have reduced the number of accidents and incidents, ships continue to pollute the oceans worldwide. Some of the cases result from human error, while others are the result of physical factors. Whatever happens, people will not be able to change the fact that ship-caused "environmental disasters" devastate habitat and marine life, endanger the survival of marine flora and fauna, cause severe ecosystem distress, and harm people's livelihoods and quality of life. From hazard identification and risk analysis systems, some solutions are proposed in this paper to address some of the marine environmental problems.

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