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Proposing a hazard identification and risk analysis system to mitigate the impact of shipping on the marine environment

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Abstract: The X-Press Pearl incident is the worst maritime disaster to have struck Sri Lanka. It has significantly impacted Sri Lanka's sensitive coastal environment, local communities, and economy. In this situation, Sri Lanka is unable to manage itself. There Sri Lanka had to seek assistance from another country. In a short period, Sri Lanka has been exposed to two major maritime disasters, MT New Diamond and MV X-Press Pearl. Due to the improper management of the above accidents, it will become a catastrophic disaster. Proposing a hazard identification and risk analysis system is an essential step toward minimizing the impact of shipping on the marine environment, identifying potential hazards, and assessing the risks associated with shipping activities in marine environments.

Index Terms: Hazardous identification, Risk assessment, risk control, Risk monitoring system

1 INTRODUCTION

Sri Lanka has been a hub of shipping since ancient times. Therefore, a large number of ships pass through the shipping lanes, which brings tremendous value as well as excellent benefits to Sri Lanka. The recent marine accident significantly impacted Sri Lanka's marine region. On May 20, 2021, the MV X-PRESS PEARL container ship MV X-PRESS PEARL arrived on caught fire off the northwest coast of the Port of Colombo with 1,486 containers loaded with cargoes such as nitric acid, ethanol, other chemicals, cosmetics, and plastic nurdles, which have a significant impact on the marine environment and damage to aquatic resources [1]. That time included 25 tons of nitric acid, sodium hydroxide, and other chemicals and 78 tons of plastic nurdles (low-density polyethylene pellets). Also, the ship had more than 300 tons of fuel in its tanks [2]. The X-Press Pearl incident is the most recent occurrence, the worst maritime disaster to have struck Sri Lanka. Sri Lankan government has declared a national emergency and has been working with international agencies to clean up the area and prevent further damage. Because of this incident, Sri Lanka's significantly impacted the marine environment, sensitive coastal environment, and local communities.

Furthermore, this phenomenon has a long-term environmental impact [3]. Since Sri Lanka has not faced such an event before, it cannot assess the environmental damage caused by accidents, especially in the marine environment. On the ship, there are still stacked container towers, many containing chemicals hazardous to the environment - some of which have leaked into the water, sparking fears it could poison marine life. In addition, tons of tiny plastic particles have washed up on nearby local beaches. Hundreds of tons of engine fuel are sealed in the underwater hull, which could also leak into the sea [4]. In addition to environmental threats, there are devastating consequences for local communities— so many environmental and social impacts. The incident has highlighted the need for a comprehensive hazard identification and risk analysis system to minimize the impact of shipping on the marine environment.

2 RISK ANALYSIS SYSTEM

Risk assessment is a risk examination related to a particular job or task. The risk assessment is to identify the presence of hazards that may cause harm to people, property, or the environment. It is vital to implement a risk analysis system against maritime disasters like Express Pearl and MT New Diamond happening in the future. Normally risk analysis system involves hazard identification, risk assessment, and control methods. The primary purpose of hazard identification is to eliminate or minimize the hazards [5]. Hazard identification of shipping in a marine environment should be performed with selected professionals. Propose hazard identification should identify all conceivable and relevant dangers to the cause. Usually, a team will include naval architects, structural engineers, machinery engineers, surveyors, human factor engineers, marine officers, and meeting moderators [6]. Before implementing a Risk analysis system, there is essential to investigate the previous maritime disaster and its impacts. Also, the professionals must inspect the annual shipping details around Sri Lankan ocean area.

The Risk analysis system procedure can be illustrated in the following way.

- Step 1: Identify Potential Hazards
- Step 2: Assess the Risks
- Step 3: Controlling Risks
- Step 4: Implement additional risk controls
- Step 5: Monitor and Review

Step 1: Identify Potential 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. The first step in any hazard identification and risk analysis system is identifying potential hazards associated with shipping activities. It includes identifying potential sources of pollution and accidents. According to the International Maritime Organization (IMO), the United Nations agency responsible for the safety and security of shipping, several hazards can be caused in ships [7]. This hazardous also be a root cause of significant maritime disasters.

These hazards include,

Oil spills from the ships - One of the significant potential shipping hazards is oil spills. Tankers, cargo ships, and other vessels that transport large amounts of oil are at risk of accidents resulting in falls, which can have devastating consequences for marine ecosystems and the communities that depend on them. In addition to oil spills, shipping also poses a risk of chemical spills, as vessels may carry hazardous substances such as chemicals, liquefied gases, or other toxic materials. The discharge of ballast water from ships can also introduce invasive species into new environments, disrupting local ecosystems and harming native species. Collisions with other vessels, grounding on reefs or shorelines, and capsizing are potential shipping hazards. These hazards can lead to loss of life, environmental damage, and economic losses, underscoring the need for effective risk management strategies to ensure shipping activities' safe and sustainable operation.

Fire - Due to flammable materials such as oil and fuel, fires can easily break out on ships. Electrical faults, overheating machinery, and welding sparks are common causes of fires. Ship fires can release various hazardous materials, such as oil and chemicals that can cause severe and long-lasting damage to the marine ecosystem, harming marine life and coral reefs. Smoke and soot from ship fires can also cause air pollution, posing a risk to marine mammals and birds. Besides environmental impacts, ship fires can endanger crew members' and emergency responders' health and safety exposed to toxic smoke and chemicals.

Explosion - Explosions can occur due to igniting flammable gases or materials on board ships. These can be caused by fuel or gas system leaks or by the ignition of volatile cargo. Ship explosions can release hazardous materials into the water, causing severe damage to the marine ecosystem by killing or injuring aquatic animals and damaging coral reefs. Moreover, the explosion can disrupt marine habitats and release air pollution, affecting the health of marine mammals and birds. Hence, ship explosions can devastate the marine environment and the communities that depend on them.

Structural Failure - Ships are subjected to significant stresses and strains, and structural failure can occur due to corrosion, fatigue, or damage from impacts. Ship structural failures can cause the release of pollutants, including oil and chemicals, into the water, leading to severe damage to the marine ecosystem. The loss can also cause the ship to sink, releasing its cargo and fuel, causing widespread damage to marine life, disrupting habitats, and contaminating the water. The release of pollutants can have long-term effects on the environment, including damage to coral reefs. Therefore, preventing such incidents and responding promptly to minimize their impact on the environment and human health is essential.

Human error - Human error, such as navigation, communication, or machinery operation, can also lead to shipping accidents and hazards. These errors can be mitigated by applying proper engineering or administrative techniques.

Step 2: Assess the Risks

After identifying a maritime hazard, the next step is to assess the marine risk. Generally, risk meansthe likelihood or possibility that harm (injury, illness, death, damage) may occur from exposure to a hazard. In risk assessment, assess the severity of that harm and the likelihood of an incident happening.

- ✓ While risk is assessed, consider the types of injuries/harm/damage that can result from the

hazard, the number of people exposed, and possible chain effects from exposure to this hazard.

- ✓ This includes examining how work is completed, whether existing control measures are in place and whether they control the harm, and looking at rare/abnormal situations and standard operating situations. A chain of events related to risk may need to be considered.
- ✓ **Determining the likelihood of harm occurring**. The level of risk will increase as the likelihood of harm and its severity increases. The likelihood of harm occurring may be affected by how often the task is completed, in what conditions, how many people are exposed to the hazard, and for what duration.
- ✓ **The Risk Ranking** Matrix is used to assess each hazard's likelihood and the severity or consequences, given from a "risk rating table."

$$\boldsymbol{Risk} = \boldsymbol{frequecy}\,(\boldsymbol{probability}) \times \boldsymbol{sevirity\ of\ the\ consequence} \quad (1)$$

The risk rating table (Fig. 1) examines the type of hazardous risk and its rating of maritime accidents. For example, we discuss Transport chemical and hazardous material ship incidents and their evaluation.

Likelihood	Consequence: Negligible 1	Minor 2	Moderate 3	Major 4	Catastrophic 5
5 Almost certain	Moderate 5	High 10	Extreme 15	Extreme 20	Extreme 25
4 Likely	Moderate 4	High 8	High 12	Extreme 16	Extreme 20
3 Possible	Low 3	Moderate 6	High 9	High 12	Extreme 15
2 Unlikely	Low 2	Moderate 4	Moderate 6	High 8	High 10
1 Rare	Low 1	Low 2	Low 3	Moderate 4	Moderate 5

Fig. 1. Risk rating table

The risk evaluation matrix is a tool used to assess and prioritize risks based on their probability of occurrence and potential consequences. Minimizing marine environment pollution involves identifying different activities or events that could lead to pollution, defining the risk criteria, assigning likelihood and impact scores, evaluating risks, prioritizing them based on risk scores, and developing risk mitigation strategies. By using this approach, we can effectively reduce marine disasters and protect the marine ecosystem.

Step 3, 4: Controlling Risks and Implement additional risk controls

It is challenging to Control the Risk when it happens. The possible way is to eliminate or minimize the

hazards at the source point. Human factors also contribute to marine disasters, such as operational failures (unsafe operations), poor ship design, poor management and organization, overworked crew, and poor security. These factors can be minimized through training, a skilled workforce, and standard operating procedures (SOPs).

Step 5: Monitor and Review

After risk is, identified, marine pollution can be prevented or minimized by implementing risk mitigation strategies. These strategies include implementing preventative measures to avoid potential risks, establishing emergency response plans in case of incidents, providing training and resources to responders, improving regulations and enforcement mechanisms, and using alternative technologies and sustainable practices. By using these strategies, it is possible to reduce the impact of marine pollution on the environment and the communities that depend on it.

In the Sri Lankan context, a strong national legal framework is necessary to manage disasters associated with maritime activities. Sri Lanka must prioritize training to mitigate the impact of such accidents. Additionally, a responsible government agency, like the Chemical Safety and Hazard Investigation Board, should be established to identify the root causes of major chemical accidents and develop sustainable strategies to protect the environment from marine disasters. New laws should be established for maritime transport and regularly updated. Furthermore, a strong legal framework is needed to recover environmental and social losses and the expenses incurred to restore the environment.

3 CONCLUSION

Due to its strategic location in the Indian Ocean, Sri Lanka has emerged as a maritime and supply hub in Asia. With increased shipping, the country has the potential for further development. However, the country is also at significant risk of maritime accidents, which can devastate the marine ecosystem. Accurate planning, hazard identification, and risk management are crucial to minimizing the damage caused by such accidents. Therefore, Sri Lanka needs to have a proper plan in place to mitigate the environmental impacts of maritime accidents that may occur in the future.

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