

The Impact of Shipping on Marine Environment - A Study of Sri Lankan Water Ways

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Abstract— Multiple causes are responsible for marine accidents and incidents. Some of them are a collision of ships, internal technical failures, human errors, or weather effects. Most of them are just ignoring the shortage of international laws, bypassing registration, which they can remotely handle by registering the vessel in any other countries than their own country. Once it happens, it can harm the marine ecosystem, ocean water and coastal region; local people daily depend on fishing in various forms and degrees. Those effects of accidents are varying from minor injuries to fatal casualties. This study reveals the most critical role of regulations in avoiding similar accidents in the future by considering two recent cases in Sri Lankan water. In both cases, Sri Lanka didn't learn the lesson from previous experience to avoid a similar accident with multiple impacts on the environment and marine biodiversity. Therefore, in the end, some crucial actions are highlighted to implement to prevent similar events shortly.

Keywords— Environmental Impact, Marine accidents, Marine Transportation, Shipping, Ocean Pollution.

I. INTRODUCTION

The global shipping industry contributes to moving millions of dollars worth of goods each day and transport finished products, commodities, and support for international manufacturing trade through various aspects. Marine, rail, air, and trucking are the four primary modes of transports within this industry. However, marine transportation has become one of the most prominent modes of transportation all over the world and mainly includes cargo-carrying commercial ships (containers, bulk carriers, oil tankers, gas carriers, reefer vessels), and non-cargo (ferries, cruise) commercial shipping [1]. In 2016, over one million marine vessels were registered, including bulk carriers, general cargo multipurpose vessels, oil tankers, container ships, chemical tankers, passenger ships, liquefied natural gas tankers, and Japan, China, Germany, United Kingdom, and Singapore recorded as the world top ship owning countries [1]. Marine industry facilitates the transport of various essential goods such as food, vehicles, clothes, household appliances, and immense importance in terms of natural resources and energy trade. It's responsible for balancing the global economy and keeping our nation and all nations together through such an advanced global market. Hence, many cities rely on their ports as a significant source of revenue. There are multiple shipping routes and ports spread worldwide, and some of the routes are recorded as the busiest shipping lanes below Figure 1 [2].

The English Channel connects England and France through the North Sea in the Atlantic Ocean. The channel is 350 miles long, and approximately 500 ships travel the channel daily. This is making a critical route in the European shipping network for products like grain, minerals, steel, and move passenger ferries, fishing vessels, etc. [3]. The Malacca Strait is another primary chokepoint in Fig. 1 and recorded as the shortest route between the Pacific and Indian oceans. It

links major Asian economies such as India, Indonesia, Malaysia, Singapore, China, Japan, Taiwan, and South Korea, and more than 83 000 vessels are travelling this route each year. Coal, oil, palm oil, natural gases are major goods transported through this chokepoint [4].



Fig. 1. Main Maritime shipping routes

The Panama Canal is also an important international waterway with more than 14000 ships navigate each year by carrying vegetable oils, fats, refrigerated foods, chemicals, petroleum products, machinery parts, etc. [3]. Similarly, there are infinite shipping routes that significantly impact marine transportation and the commercial circulation of the global economy. Especially, Bosphorus Strait, Suez Canal, Hormuz Strait, Danish Straits can be primary chokepoints. At the same time, Magellan Passage, Dover, Sunda Strait, Taiwan Strait can be identified as some of the secondary chokepoints in the global trade of goods and commodities which support the maritime industry [5].

Most of the activities related to marine transportation are mainly associated with adverse environmental effects. It was

estimated that 33% of global fossil fuel combustion, 3.3% of carbon dioxide emissions, 10%–15% of the world's SO_x and NO_x emissions, approximately 1.8 million tons of PM emissions account for marine transportation [1]. On the other hand, GHG emissions from the shipping industry keep increasing at higher rates. For example, in 2007, global CO₂ emission from the shipping industry was estimated at 816 million tons of CO₂ eq. It was recorded as 961 million tons of CO₂ eq in 2012, and researchers revealed that this would rise by 20% in 2030 [1]. According to the global marine environmental pollution and prevention and control- 2017 report, multiple causes are involved in shipping-related pollution. For example, 18% of pollution caused by structural damage, 16%, 13%, 11%, 9%, 7% of pollution was happen due to severe weather conditions, collision, grounding, fire/explosion, loading/ unloading, respectively and 26% pollution causes are still unknown [6].

In addition, vessel noise emissions and movements also cause ecosystem disturbances like habitat and vegetation destruction, damage to seagrasses, coral reefs, etc. Ship operations are the primary factor of marine pollution such as oil, chemical transportation, maintenance activities, etc. Maintenance and ship breaking activities are also associated with adverse environmental effects like discharging harmful chemicals and substances into the environment, including asbestos, sewage, organo-tins, bacterial contaminants, and heavy metals [7]. Other than that, oily water discharge from ships, tanker accidents, accidental spillage during terminal loading, ballast-water discharged from ships at ports, marine machinery exhaust, anti-fouling paints, sound pollution are familiar sources of pollution from ships [8]. Furthermore, researchers identified that over 100 000 container ships had been lost at sea each year, and ports, channels, beaches have high-risk potential due to discharging plastics, sewage, industrial waste, cargo residues from bulk carriers, etc. [9].

A. Shipping Industry and Environment Pollution – Local Context

When moving on to the Sri Lankan context, the island of Sri Lanka lies near the center of the Indian ocean, and it consists of a mesmerizing, enthralling, pleasing ecosystem. Sri Lankan ocean is unique with vibrant marine habitats (whales, turtles, dugongs, etc.) and rich marine biodiversity with many fauna and flora. Nevertheless, sensitive ecosystems like mangroves, shallow coral reefs, seagrasses, muddy tidal flats, sandy beaches, rocky shores, lagoons, estuaries near or within the coastal area accidents can have high consequences such marine ecosystems.

Moreover, Sri Lankan ports are the most strategically located ports for the vessels moving from west to east and east to west as it places in the middle of the global trade and shipping network. This strategic location creates Sri Lanka as a crucial logistic service hub for distributing goods and logistic services [10]. In addition, Sri Lanka has a larger exclusive economic zone which is eight times larger than the Sri Lankan land area, and more than 4000 ships are entered annually [11].

Sri Lanka has four major seaports located around the island, namely Colombo, Galle, Hambantota, and Trincomalee. Colombo has a deep natural harbour that receives substantial traffic from nearby shipping lanes, and Colombo port is ranked among the top 50 world container ports based on the volume of the containers handled [12]. Besides, multiple shipping lanes are located around the country and networked with various international shipping ports, as illustrated in Figure 2.

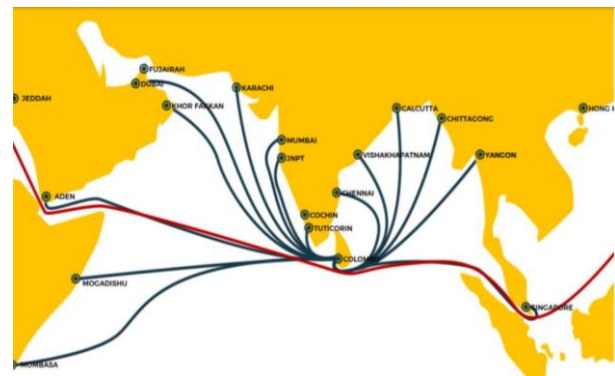


Fig. 1. Major shipping lanes networked with Sri Lanka [11]

However, compared with other countries, Sri Lanka has less infrastructure to combat maritime emergencies like oil spills and chemical spills, thus possessing very significant risk [10]. Concerning all states from the global and local level, it was revealed that the development of world industry directly affects ocean pollution and causes a significant risk to the marine environment.

II. SHIPPING ACCIDENTS

Unsuitable conditions involving shipping activities are referred to as a maritime accident, incident, or marine casualty. Maritime accidents, mishaps, and near-misses are all examples of what is referred to as a "marine incident." An accident is an unintended incident with negative consequences (injury, death, economic loss, environmental harm, and property loss) [13].

The majority of accidents are sourced from Lloyd's database and the Maritime Accident Investigation Bureau (MAIB) of the UK [14]. Maritime accidents are recorded in a Turkish database maintained by the Turkish Ministry of Transport, Maritime Affairs, and Communications, as they are in many other countries. Between 2008 and 2012, Figure 3 displays the number of marine accidents and incidents, the number of vessels involved in maritime accidents and incidents, and the number of people killed or injured. Vessels flying both Turkish and international flags are included in the statistics. In 2008, there were 206 occurrences off the coast of Turkey [13].

According to the previous studies [13], The following shipwrecks were reported from 1960 to 2009 that caused sea pollution in the Turkish sea.

On October 25, 2009, the M/V vector sunk in the Black Sea, causing marine contamination from waste pollution and oil leaks. On October 22, 2009, the M/Y Liberti caught fire,

spilling 50,000 litres of diesel oil into the Aegean Sea. On October 1, 2009, 30m Jet A1 (Jet Fuel) spilt from M/T Breeze into Mamara Sea. M/Y Marinel 1 sunk on September 30, 2010, causing marine pollution. On January 19, 2010, the M/V Orcun sank the Mamara Sea [13].

M/V Zorbey landed on November 3, 2011, causing pollution in the Mediterranean Sea. The M/V Amstelborg collided with the jetty, leaking 30 tons of petroleum into the Mamara Sea. On December 14, 1960, near Kanlca Point, the Yugoslav flag, M/T Petar Zorani, collided with the Greek tank, M/T World Harmony. As a result, 20 officers and crew members died, and 18,000 tons of oil escaped and polluted the environment. Traffic was halted for several weeks as a result of the fire [13].

M/T Independenta is a big Romanian crude tank that exploded after colliding with a Greek ship at the Bosphorus' southern entrance in 1979. She caught fire and crashed, killing nearly the whole tank crew. There was a minor leak from the tank from November 17 to November 27. It is believed that 30,000 tons of crude oil were burnt, with 64,000 tons poured into the sea. The sprayed crude oil plummeted swiftly. A 5.5-kilometre-diameter seafloor is covered with bitumen, with a median concentration of 46 g / m. Only nine benthos species have been documented alive in the region, with a 96 per cent death rate [13].

In 1991, the Rab Union-18, a Lebanese flagship ship carrying live sheep, collided with and drowned near the Fatih Bridge. The ship has sunk 20,000 sheep and oil to a depth of 32 meters and has yet to be towed onshore. The sinking of M/S Rab Union-18 after colliding with Madonna Lily, as well as the rotting of dead animals, would result in significant contamination in this vital waterway [13].

M/T Nassia crashed with M/V Shipbroker on March 13, 1994, in Istanbul. Twenty-seven persons were killed. The strait's traffic was halted for many days, and the ship was entirely absorbed in flames. Following the accident, 20,000 tons of oil were thrown into the sea, harming the marine ecology and contaminating all neighbouring bays and beaches [13].

On December 13, 1997, a TPAO (Türkiye Petrolleri Anonim Ortaklığı) tank in the Gulf of Tusla caught fire, spilling 1,500 tons of petroleum into the water. The sample required to examine the effects of oil spill pollution on marine life due to thick oil slicks could not be taken in the inner section of the bay in the week after the TPAO tank disaster. The high death rate of fish eggs and larvae, particularly after the TPAO disaster, demonstrated that the oil and metal pollution in the water harmed the organism. After approximately seven months, the amount of oil contamination returned to normal [13].

On December 29, 1999, the M/T Volganefit-248 grounded in Florya while carrying 4,000 tons of gasoline and broke into two parts, spilling 1500 tons of oil into the sea. The contaminated recreational beaches required roughly two years to clean up [13].

The MAIB database contains information on all events involving UK ships in which authorities have received an emergency statement [14]. In 2019, the MAIB received

reports of 1,090 accidents, such as casualties and incidents involving UK vessels or UK seas. These were joined by 1,192 more ships. 433 is not included in this report. They were personal accidents that did not result in actual or prospective harm to the vessel. There were 657 accidents involving 730 commercial boats, resulting in actual or prospective vessel damage [15].

According to the MAIB report in 2019, all accidents are classified into four categories, very serious, serious, less serious and marine incidents. These categories are defined as follows. A very serious maritime accident results in the total loss of a ship, the loss of lives, or significant pollution. A serious maritime accident is defined as an occurrence that causes one of the following outcomes: (a) the ship cannot proceed due to substantial engine immobility, substantial accommodation damage, severe structural damage. (b) Pollution, (c) Drugging or breakdown that necessitates coastal assistance. A less serious maritime accident is a description of any maritime accident that is very serious or serious, and a Marine incident is an occurrence or sequence that happened directly related to the action of an endangered ship that is not described above [15]. Based on the report in 2019, there is a significant increase in less serious and marine incidents that are highly likely to occur, compared to very serious and serious accidents.

A. Why It Has Commonly Happened

According to Faturachman and Persada's research [16], 88% of accidents in rivers, lakes, and across to the Admiralty Court are caused by human mistake, with just a few incidences in the waterways caused by natural circumstances. All of these factors/causes are given below;

1. The human factor is by far the most important, including the following: Inability to avoid various problems due to negligence of staff members;
2. Technical factors are usually associated with inaccuracy in ship design, damage to parts of the ship or vessel that caused the ship to capsize due to neglect of ship maintenance, and shipwreck when experienced;
3. Natural factors are often considered to be the leading cause of maritime accidents due to bad weather. Storms, high waves because of seasonal / hurricane, large currents, resulting from which the fog has limited visibility [16].

Another study discovered that high-level organizations, such as organizational influence and insecure oversight, are the primary causes of major accidents. The Human Factor Analysis and Classification System (HFACS) model separates these accidents from those classified as serious and less serious. The highest-scoring causal variables are found among preconditions for dangerous acts and unsafe acts [17]. Statistical studies have lately indicated that human error is the principal cause of the majority of marine accidents. Cicek's study report cites the following factors [13].

1. Natural conditions such as tide and tidal stream, severe wind, reduced visibility, storm seas, darkness etc.
2. Technical failures include corrosion, steering failure, engine failure, or hull failure arising from defective

materials or construction or by the shore-based installations, such as aids to navigation.

3. Route conditions may include navigational error (inaccurate nautical charts, decisions based upon old surveys, narrow channels)
4. Ship-related factors such as the larger size of the ship, hence less manoeuvring capability and stability or draught constraints.
5. Human errors may include lack of relevant knowledge and expertise, technical incapacity, poor lookout, failure to follow procedures and norms, carelessness in controlling a ship, misinterpretations of radar data, exhaustion and lack of awareness, overworking, exhaustion, insufficient rest times, etc.
6. Cargo-related factors primarily include dangerous goods and heavy cargoes.

According to the Council of Canadian Academies shows some of the factors that increase the risk of accidents or mishaps. Human factors, such as operational failures (unsafe operations) and latent circumstances, are also cited in the study as the primary cause of a shipwreck (poor ship design, poor management and organization, overworked crew guidance and poor security); other factors also influence shipping accidents through a risk environment. The report was listed three risk environments.

1. The physical risk environment (Limited waterways and storms)
2. The socio-economic risk environment (Inadequate vessel maintenance or poor safety culture)
3. The policy risk environment (Insufficient maps, charts and navigation supports) [18].

Another study done by Zhang and Li [19] has mentioned that Investigations into the shipwrecks show that more than 30% of the accidents were caused by bad weather, and another 25% could not be fully explained. On the other hand, the sea surface is unexpectedly complicated under changing weather conditions, especially over short periods. Random waves of various heights, lengths, and periods make up the sea surface [19].

B. Consequences of a Shipping Accident

Maritime accidents harm individuals, the marine environment, ships, coastal landfills and activities in varying degrees and volumes. Human errors, resulting in oil spills, waste sludge spills, oil spills, or bunker accidents, contribute to marine pollution. Shipping accidents continue to represent a serious threat to marine and coastal ecosystems, resulting in considerable environmental and economic harm [13]. Hazardous and noxious substances (HNS) leaks are another pollution of the marine environment. The protocol of the OPRCHNS (Protocol on Preparedness, Response and Co-operation to Pollution Incidents by Hazardous and Noxious Substances) defines HNS as a substance other than oil, which, if introduced into the marine environment, has the potential to endanger human health, harm life and marine life, damage facilities or interfere with other legitimate uses at sea [13].

However, in most cases, even after the largest oil spill, affected habitats and associated marine life can be expected to

recover extensively over several seasons. One or more of the following mechanisms can affect the oil environment [13].

- Physical smothering affects physiological functions.
- Chemical poisoning can have fatal or sub-lethal effects or cellular damage function;
- Environmental changes, primarily the loss of critical species from the community and habitat acquisition by opportunistic species.
- Indirect impacts include loss of habitat or habitat and removal of ecologically essential species results [13].

The nature and duration of the impact of an oil spill depend on a wide range of factors (size and type of oil spill, its behaviour in the marine environment, environmental conditions and physical characteristics, location and time of the spill especially). Other essential factors are the biological composition of the affected environment, the environmental significance of the constituent species and their susceptibility to oil pollution. The selection of appropriate cleaning methods and the effectiveness of the operation can also have a significant impact on the outcome of a leak [13].

Marine pollution from oil spilt cause the formation of the oil film in the seawater that interferes with the exchange of air between the atmosphere and seawater, affecting the absorption, transmission and reflection of electromagnetic radiation on the ocean surface. The long-lasting oil film covering the polar area increases the endothermic capacity of the ice. It accelerates the melting of ice, which is affected by global sea-level changes and long-term climate change. Seawater and seawater oils can dissolve lipophilic components in pollutants such as halogen hydrocarbons and slow down interaction and conversion rates [6].

The Council of Canadian Academies [18] reported three factors that affect environmental impacts: Physical sensitivity (substrate type, depth), Biological Sensitivity (Species, Habitat) and Human and Socio-Economic Sensitivity (Economic Activities). The potential environmental impact varies depending on the time of year, and the quantity and type of goods discharged [18].

Shipwrecks on the high seas can have a broad range of social, cultural, health, and economic consequences. These consequences can directly or indirectly influence economic losses due to injuries, supply chain disruptions, or environmental impacts. For example, an oil spill can have an economic impact (loss of tourist income), social impact (disruption of community relations) and health effects (exposure to chemicals in an attempt to clean up Sick). Other than that, the closure of fisheries will result in the loss of income to fishing communities and the loss of income to the fishing industry, which can lead to financial distress [16]. Oil pollution by shipping accidents prevent photosynthesis, reduces the amount of oxygen in seawater, and destroys the regular physical activity of organisms, thereby gradually depleting fisheries resources for fisheries. Due to the presence of oil pollutants and odours, any remaining fishery resources are also unusable. Living in seawater for 24 hours can be with fish and oyster oils containing 0.01mg / L of oil, 2 ~ 3h if the concentration increases to 0.1mg / L, it can form an odour. Oil film formation can restraint re-oxygenate water, affect the

growth of ocean flora and damage the marine ecological balance [6].

Oil pollution damages coastal scenery and the coast. Oil from oceans and waves quickly accumulate on the coast, polluting the coast and destroying tourism resources. In 2002, the Panamanian oil tanker "prestige" spilt oil, destroying the beauty of Spain's Galician coast and causing pollution to the shore and coastal beauty. Oil from oceans and waves quickly accumulate on the coast, polluting the coast and destroying tourism resources as an economic impact [6].

Marine oil pollution directly or indirectly affects human health, such as Anesthesia and suffocation, chemical pneumonia, and dermatitis. Like gasoline for drug poisoning, acute poisoning can damage the central nervous system and respiratory system; Chemical pneumonia can be caused by inhaling large amounts of diesel oil in the short term. The oil in the ocean and the food chain causes severe damage to human health. Petrol, diesel, kerosene in toxic and harmful substances affect the human nervous system, urinary system, respiratory system, blood system, circulatory system, and other hazards [6].

III. METHODS AND METHODOLOGY

A. Case Study: 01

One of the recent incidents was MT New Diamond which was carrying 270,000 metric tons of crude oil from the port of Meena Al Ahmadi in Kuwait to the Port of Paradip in India. According to the information received from the ship crew, on September 03, 2020, a fire erupted in the ship's boiler in the main engine room, killing a Filipino crewman [20]. The first phase of the accident initiated 38 nautical miles away from the Sri Lankan shore [21].

However, after this incident happened, the fire was doused entirely after several days with the joint mission with the Indian Navy. Even though 270 000MT of crude oil unaffected by the fire, an unspecified amount of fuel (around 1700 MT) required to operate the ship ruptured in the blaze that destroyed the engine room and leaked to the ocean (Figure 3).



Fig. 3. Several ships joined the weeklong battle to douse the fire that erupted inside the MT New Diamond on Sept.3 [22]

Even though Sri Lankan Authorities demanded 3.4 bn rupees, they only compensated 442 Million as the expenses for fire extinguishers and rescuing the crew members. That was

the first incident that the Sri Lankan government faced: not even regulating how to get compensation for similar events.

However, environmental damages cannot be easily calculated within a short period as many consequences are coming in the future. Only calculations can be done approximately based on the losses of the fisheries industry, property losses, marine life damages and impact on tourism. Long-term environmental impacts cannot be declared after the incident as severe environmental damage consequences are slowly happening.

One of the main issues with an oil spill is that marine mammals have to surface for breathing, so they have to pass through the oil layer, which inhales the toxic substances. One of the essential parts of the MT New Diamond was registered in Panama and owned by the Greek company Porto Emporios Shipping Inc [22].

B. Case Study: 02

The following recent shipping accident eight months after the MT New Diamond accident, which was a fire on MV X-Press Pearl on 20 May 2021. The fire on MV X-Press Pearl, a Singapore-registered ship, broke out on 20 May and has been burning ever since (02 June 2021, 19:30). The Sri Lankan and Indian navy's joint mission struggled to wipe out the flames more than the continuous 10th day (Figure 4). The ship carried 25 tonnes of nitric acid, sodium hydroxide and other dangerous chemicals and 28 containers of raw materials used to make plastic bags. It also had more than 300 tonnes of fuel in its tanks [23]. It is reasonable to fear that the chemical spill has already caused untold damage to Sri Lanka's coastline, including the popular tourist resorts, as many of them are located on the coastal areas of Negombo and Kalutara, with beaches thickly coated in macroplastics and an oil slick visible in the surrounding ocean. The plastic pellets used to make plastic bags can be fatal to marine life. It is already begun to washing up the beaches with dead sea turtles, dead fish and birds in the Colombo coastal area. Most Sri Lankans daily consume fish for their diet, and will be consequences for their food chain as pellets can soak and absorb the chemicals from the environment; when we eat whole fish, we will also be eating these chemicals. Members of the Sri Lankan Navy and some other environmental organizations, together with village people, beaches are still cleaning and removed more than 1000 tons of waste out of the beaches (Figure 5).



Fig. 4. The fire extinguishing of MV X-Press Pearl [24]



Fig. 5. Members of the Sri Lankan Navy clean a beach in Colombo after tons of plastic pellets washed ashore [24]



Fig. 6. Smoke rises from the container vessel MV X-Press Pearl engulfed in flames off Colombo port, Sri Lanka, Tuesday, May 25, 2021 [25]

At the same time discussing ocean pollution, it is important to consider air pollution happening with the cause of the fire (Figure 6). The air pollution impact cannot be ignored as that will emit a massive amount of greenhouse gases and toxic vapours to the atmosphere. Those air pollutions cannot be removed once it is emitted from the fire. Therefore, acid rains, deposition of particulate matter on the vegetation, inhalation of polluted gases cannot be controlled in this situation.

IV. CONCLUSION

A. Case Study 01: Conclusion

- In this accident, 2 Mn barrels of oil would be entering our sea. The disaster would mean a complete halt of fishing in the northern and eastern sea, death of marine life, corals by decades of consequences. Luckily, the major accident was avoided with minimum environmental damages.
- There was no preparedness to quickly respond to spills off Sri Lanka, whose waters heavily traversed ships carrying oil from the Persian Gulf to East Asia. Sri Lanka's waters are also home to a wealth of marine biodiversity, including coral reefs, whales, and economically vital fisheries — all of which would be impacted by oil spills. However, the environmental impact was not adequately investigated along the timeline to accurately analyzed the damage. Sri Lanka did not have a team of experts in marine disaster management and risk analysis to control similar incidents and minimize environmental damages.

B. Case Study 02: Conclusion

- It seems that they were not ready for the second time to handle a similar kind of situation. They have not learnt a lesson to manage disasters even they had previous experiences. There are several reasons it can summarize; such as lack of resources to deal with such a fire, not having protocols in place to seek necessary support from better equipped marine powers, not having mutual agreements with other countries to face and avoid similar situations, not equipped with proper technical instruments as well as knowledgeable people. It should implement the disaster planning and risk analysis body to prevent a similar situation in the future.
- This time amount of oil leakage to the ocean, plastic and microplastic impact, chemical impact on marine life not even in the imagination level. The worst consequences yet to have come. Our response time on disaster management is one of the critical issues to avoid further damages. In a case like this, even actions that have taken a minute delay also significantly impact the environment. It seems that many residents nearby coastal area started to collect those potentially hazardous materials. We were even late to avoid that as people seem to be ordering anything and everything, they feel is valuable. This is another lesson learning event to prevent a similar situation in future.

What are the actions taken by other countries

International Maritime Organization (IMO) is the only available international body to develop and implement the regulations and recommendations to avoid marine disasters and cooperate with countries. The MARPOL 73/78 Convention is the main international convention that safeguards the marine environment against ship pollution [26]. The technical requirements of MARPOL are included in six separate Annexes which can be summarized as below:

- Annex I—Regulations for the Prevention of Pollution by Oil (oil from operational measures as well as from accidental discharges).
- Annex II—Regulations for the Control of Pollution by Noxious Liquid Substances in Bulk (some 250 substances were evaluated and included in the list; In any case, no discharge of residues containing noxious substances is permitted within 12 miles of the nearest land).
- Annex III—Prevention of Pollution by Harmful Substances Carried in Sea in Packaged Form
- Annex IV—Prevention of Pollution by Sewage from Ships (the discharge of sewage into the sea is prohibited).
- Annex V—Prevention of Pollution by Garbage from Ships (complete ban imposed on the disposal into the sea of all forms of plastics).
- Annex VI—Prevention of Air Pollution from Ships (Sets limits on sulphur oxide and nitrogen oxide emissions from ship exhausts)

To maintain proper pollution control mechanism by marine operation, including maritime accidents, most governmental authorities from many nations follow those recommendations.

Over 170 countries are with the MARPOL agreement, given in Figure 7 with the green colour.



Fig. 7. Parties to the MARPOL 73/78 convention on marine pollution [27]

The Protocol of 1978 has been adopted in response to a spate of tanker accidents in 1976-1977. Those six amendments are adopted through the period to prevent and minimize pollution from ships - which includes both accidental pollution and that from routine operations collaboration with each other. In 1997, Sri Lanka also joined with the MARPOL 73/78 to avoid and maintain marine pollution. Moreover, the government of Sri Lanka has been established 'The Marine Environment Protection Authority fallen under the Marine Pollution Prevention Act No. 35 of 2008, to prevent, control, and manages the Pollution of Sri Lanka's Marine Environment [28]. Even with the MARPOL partnership, those tragedy has happened with irreversible environmental damages. Therefore, immediate actions have to be implemented to avoid similar kinds of disasters in future.

If it is considered case study 02, Sri Lankan officials believe the fire was caused by a nitric acid leak which the crew had been aware of since 11 May. In that case, they knew the ship is coming towards Sri Lanka by violating Annex. II as nitric acid is a harmful substance. However, ship authorities were not appropriately informed, and Sri Lankan authorities monitoring did not avoid sailing from the original port.

V. RECOMMENDATIONS

- At least Sri Lanka has to create a body of risk analysis to evaluate the previous incident with the possible root causes to avoid future incidents. Moreover, they should start re-thinking of modifying marine risk assessment to identify their need to strengthen their capacities to address major oil spills as they are in the busy stretch of the Indian Ocean, with 200 to 300 ships passing it daily. Much of the traffic consists of oil tankers carrying crude from the Persian Gulf to East Asia.
- Now it is time to start risk analysis and disaster planning for marine accidents. As we were ranked one of the worst ocean polluting nation, this type of incidents will boost the rank. It has to be taken immediate action to start with mutual agreements with neighbouring countries such as Thailand, China, India, Indonesia, Maldives, Seashells, Australia, and even Middle-East countries to avoid and control marine accidents environmental damages. Without considering that it does not belong to their territorial coastal shore authority, those countries should take immediate action to wipe out the fire and avoiding any oil, chemical leakages to the Ocean. In the end, the Ocean we cannot consider as the Indian Ocean or the Pacific Ocean, or which is the impact on one country, it is interconnected, and consequences will be for everyone worldwide.
- It is vital to operate chemical safety and hazard investigation board to simulate the root causes of those accidents and analyse the possible root causes to prevent similar kind of future accidents. Those investigations should be arranged as simulation studies to gain and improve the knowledge of students, scientists and experts, and many parties involved with environmental pollution prevention mechanisms. Once the accidents happened and settle down the media highlights and public concerns, it should not stop as an isolated case. Those should use as an asset to implement the safety standards and collaborations with other parties to avoid and implement safety in the future. A similar type of hazard analysis bodies is functioning in other countries, such as; chemical safety and hazard identification board of the United States of America, an independent federal agency appointed by the president [29].
- Immediate actions should be taken to fulfil the need for being the party of MARPOL 73/78 Annex: 1-6. In that case, it is essential to monitor shipping vessels that are sailing through Sri Lankan Waterways, not just only the Sri Lankan controlled shipping route. Therefore, shipping routes monitoring is essential for international authorities to be updated knowledge of cargo those ships are carrying, any leakages or damages, any sick or infected on board to avoid future accidents.
- Interest and active participation of all concerned are essential factors for eliminating causes of accidents and incidents. Prompt reporting of accidents is of primary importance for a successful and effective response that would result in the Correction of the causes. Therefore, all countries should come to a mutual agreement to follow this order.
- Once any chemical leakage or fire is identified, the nearest coastal authority should take immediate action to avoid and control that even though they will not have the proper equipment or human experts to concern that, they should not continue sailing without attending to prevent that. Therefore, all parties with the MARPOL should come to a mutual agreement to follow that.
- Even though minor consequences, incidents and near misses should be reported to avoid severe accidents in the future. Near misses could be warnings or indications of serious problems coming in future. Each near miss is a sign that something is wrong with the present situation. Proper follow up is necessary to prevent accidents of significant proportions or eliminate them. Near miss, analysis has to be done by responsible authorities and should be informed to all countries in the shipping route for them to be aware and ready.
- Sri Lankan authorities should develop oil-absorbing techniques and research bodies to minimize the impact of oil spillage hazardous accidents. As an example, the oil-

absorbing mat can be designed with human hair. As human hair is a lipophilic material, human hair repels water but actively absorbs oil. However, further experiments have to do to improve the inventions. The main advantage of an oil-absorbing mat with human hair is that raw material is just widely available waste regenerating. Therefore, the raw material has zero cost, and it is a solution for human hair waste disposal. However, the size of the mat, the total amount of mats required has to be analysed by considering the effective area of the clean-up process in the shoreline.

- To achieve Annex VI of the MARPOL, many shipping companies use low sulphur fuels to minimize exhaust emissions. However, low sulphur fuels will reduce the fuel's flashpoint by increasing the potential ability of a fire (not biofuel). Many countries in western Europe have their emission standards for marine ships passing through their territorial waterways. However, blended low sulphur fuels will not be compatible with old ships to achieve the targets. However, many cargo ships have been operating with exhaust gas capturing technology to avoid that low sulphur fuel risk as they use regular fuel and clean the flue gas before emitting it into the atmosphere. Therefore, authorities have to check the type of fuel they use when they ask permission to enter territorial waterways.
- Sri Lankan authorities should check the registered body of the cargo ship, owner of the vessel, goods on board, fuel type they are using, safety and health standards on board to avoid fire and accidents, insurance policy and the conditions of the insurance terms as well as the quality of the ship which is manufactured year, and the present state of the operating standards. Unless otherwise, the government should not permit them to sail them through waterways. Once accidents happened, no appropriate responsible party took the responsibility and paid the insurance for the damages. Because anyone can register their ships in other tax-free countries such as Panama without operating the company from that country, in that case, the registered country, owner, headquarters of the shipping company are in different locations and not easy to track down to get proper response for the liability losses.
- Even ultra-high penalties are not bringing back the original nature. It was there before the accidents. Therefore, prevention is better than cure.

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