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Maritime Tanker Accidents and Their Impact on Marine Environment

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Abstract. Shipping is a fundamental mode of transportation for 85 per cent of the world trade, supplying raw materials, energy, manufactured goods, foodstuffs etc. to the global population, is carried by international shipping industry. In such busy traffic, unfortunately, accidents are inevitable events. Large numbers of casualties occur at sea almost every day. Human loss and marine environmental damage, among others such as financial and property losses, are the most crucial and hazardous disasters caused by maritime accidents. There are several causes playing role in maritime accidents such as natural conditions, technical failures, route conditions, ship-related factors, human errors, cargo-related factors. There are also quite many types of maritime accidents; they include oil spill, ship grounding, fire, to mention a few. The impact of maritime accidents on the marine environment differs from one another. The main purpose of this paper is to determine and analyse the effects of maritime accidents on the marine environment. The analysis was based on data published over the past 56 years involving spills of 7000 tons oils. Within this scope, firstly, the literature related to maritime accidents involving spills was reviewed and then the statistics of maritime accidents and their impact on marine environment worldwide were analysed and evaluated.

1. Introduction

Despite the fact that since ancient times ships were one of the factors polluting seas, the people had not been aware of its permanent damages on the environment. Since the steam ships took the place of tall ships at the end of the nineteenth century, the marine pollution accelerated because of oil and oil products used and carried by ships. Especially growth of tanker fleet carrying oil and oil products and accidents spilling oil into the oceans draw attention to the permanent harms of maritime transportation during the twentieth century U Thant who served as Secretary General of the United Nations between 1961 and 1971 and the Club of Rome inspired a change of attitude, which raised concerns about the environment and its protection [1]. Oil spills caused by maritime transport of oil and oil products are still an important source of marine pollution, especially in oil terminals, main production areas and transport routes. In order to prevent or at least minimize the hazardous effects of marine accidents, we first and foremost need to recognize the actual size and details of the maritime accidents. With this aim, major oil spills over 7000 ton since The Torrey Canyon accident in 1967 and the effects of the accidents on environment will be examined.

2. Figures About Marine Transportation of Oil and Oil Products

That 85 per cent of world trade which supplying raw materials, energy, food etc. to the global population uses maritime transportation, makes shipping take the first place among other modes of transportation. As of 2016, the number of world's merchant ships trading internationally raised up to around the world. According to this statistics [2];

a) 11,614 Bulk Carriers,
b) 16,433 General Cargo Ships,
c) 13,222 Crude Oil And Chemical Tankers,
d) 5,107 Container Ships,
e) 8,498 Ro-Ro and Passenger Ships,
f) 1,921 Liquefied Natural Gas Tankers.

Despite the fact that liquefied natural gas tankers which contain flammable material has the potential to be an extremely dangerous chemical, statistics show that liquefied gas carrier ships are rarely involved in marine accidents [3] because of low number of the fleet and the gas is transported in liquefied form in tankers without contact with air or any other source of oxygen which avoids any possibility of explosion. Also its place in the World Merchant Fleet is another factor which keeps its slice in marine accidents: as seen in Figure 1, it is estimated that the liquefied and natural gas carrier ships have a share of 4% in the World Merchant Fleet. On the other hand, general cargo ships have the largest share with 32% in marine accidents.

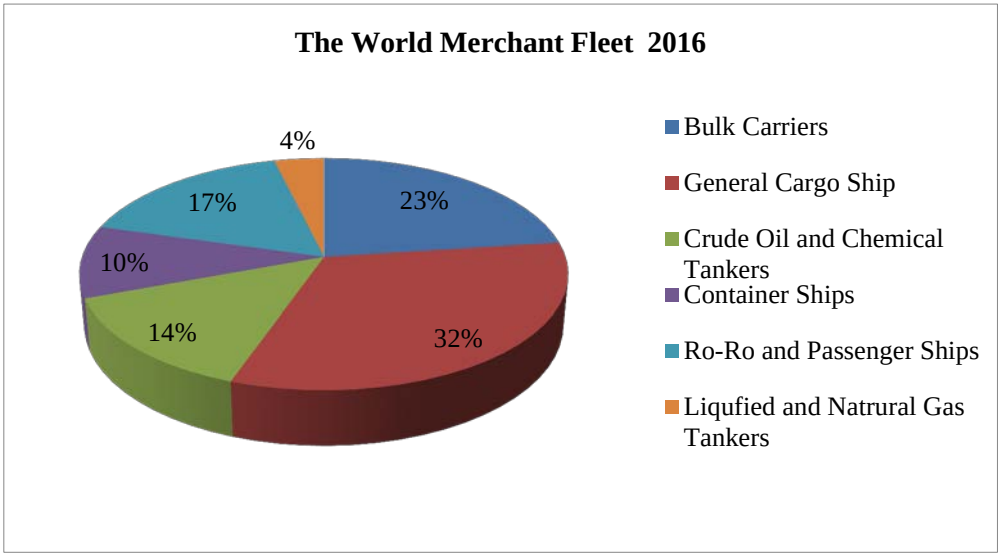

Figure-1 The World Merchant Fleet

Shipping traffic in the oceans and seas are quite heavy. Especially maritime transportation of oil which keeps the global economy running, with tankers has been increasing. Worldwide production of crude oil rose from a little over 63 million barrels per day in 1988 to about 92.6 million barrels daily in 2017 [4]. Increase in production and consumption of oil has extended its portion in marine transportation Figure-2 depicts the volume of crude oil that is imported or exported by seaborne transportation from 2010 through 2017.

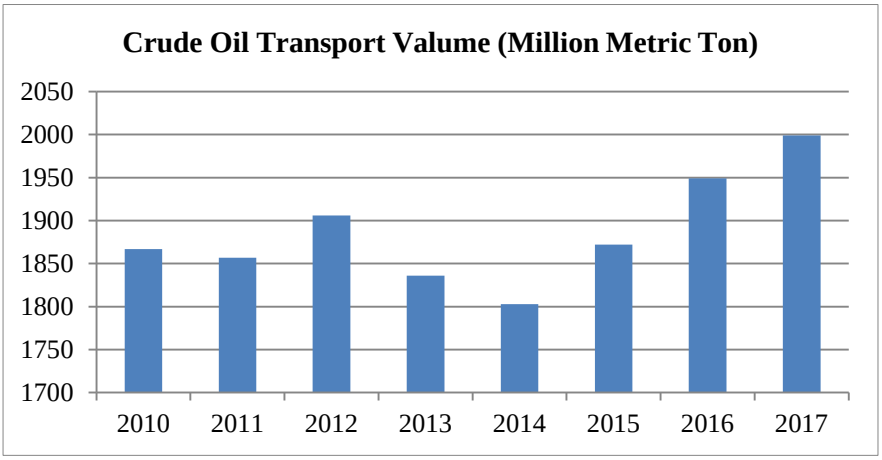

Figure-2: Crude oil seaborne transportation from 2010 through 2017

Since 1960 the rising oil production levels in exporting countries, together with increasing demand and refining capacities in oil importing countries has resulted in global increase of vessels for oil transportation in order to meet growing demand. In recent years the number of oil transportation tankers has increased continuously since the first of the sea going super tankers began service in early 1950s. The number of crude oil tanker is highlighted in the Figure 3 between 2008-2017 years. [5]

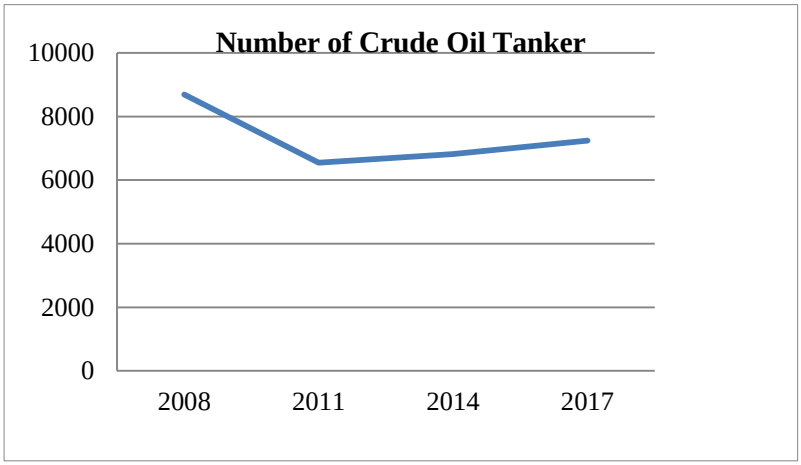

Figure 3: The number of crude oil tankers in 2008-2017

2. **Figures about Marine Accidents and Major Maritime Oil Spills**

As shipping involves high risk operations, even in the age of precision navigation and satellites, a great number of casualties still occur at sea. Even advanced and sophisticated navigational devices and enhanced communication technologies have been unable to avoid maritime accidents [6]. Maritime accidents have dramatic consequences; lives lost damage to the environment, financial and property loses. Maritime oil spills pose a terrifying danger to sea and shores ecosystems alongside human lives. Since most of petroleum-related chemicals are toxic and carcinogenic, oil spill damages fauna and flora of the seas by accumulating in the tissues of marine organisms and then disorders the marine food chain.

The statistics of maritime accidents and spilling during last five decades about above 7000 tons of petrol/petroleum-derive products is displayed in Appendix (Summary of Spills); 1967-1977: 461700 tons, 1978-1988: 989000 tons, 1989-1999: 758700 tons and 2002-2007: 122600 tons of oil or its products spilled into the marine environment. Although the number of the latter has decreased significantly during the past decades, catastrophic accidents such as the sinking of the Sea Empres

tanker Milford Haven Passage/England and Prestige tanker near the coast of Galicia (Spain) still pose an important threat to marine and coastal ecosystems, causing extensive environmental and economic damages [7]. Technical or human failures, route or natural conditions, ship or cargo, they are important factors and play an important role in maritime accidents. Nearly 5.747.000 tons of oil/crude oil has spilled into the sea until 2017 [8].
The main causes of maritime accidents display below in Figure 4.

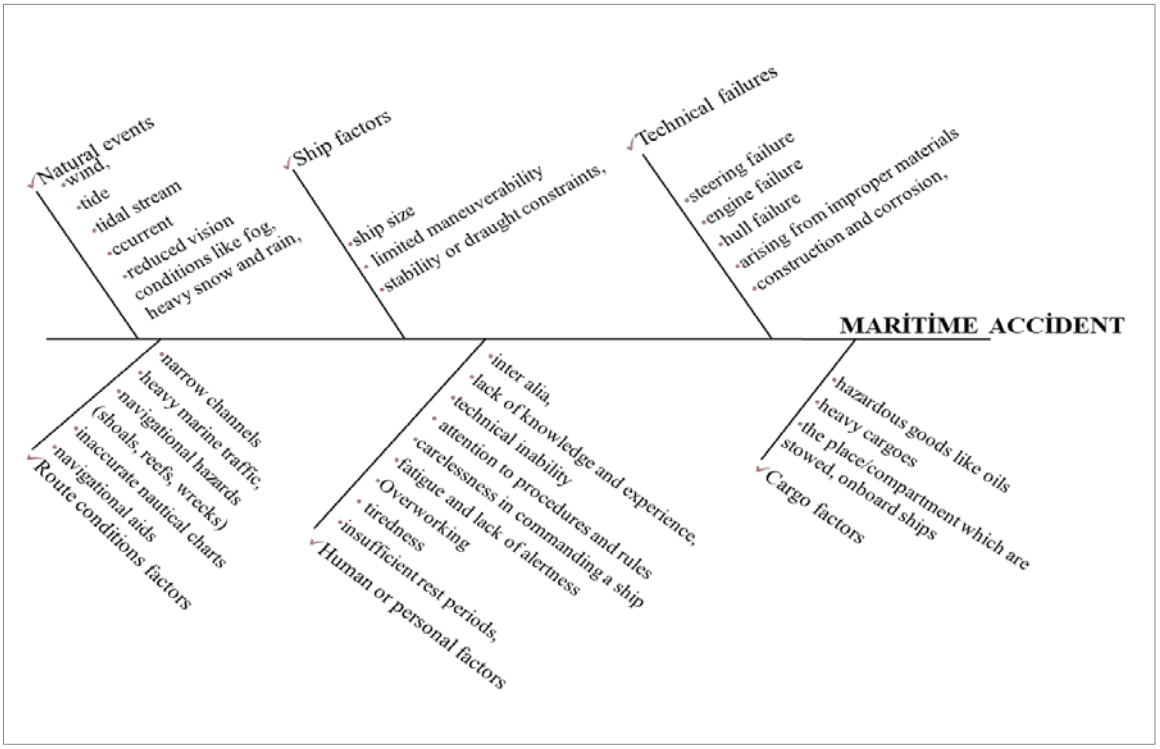

Figure 4: The main causes of maritime accidents

The terms “marine accident and incident” and “marine casualty” denote undesirable events in connection with ship operations [6]. An accident is an undesired event that results in adverse consequences, for example injury, loss of life, economic loss, environmental damage, and damage to or loss of property [9]. Accidents are due to an unexpected combination of route/sea/weather conditions or events. Bigger size brings corresponding increases in cargo and passenger capacity; hence when an accident or a casualty occurs, the risk of life and property immediately becomes higher. Reduced ship manoeuvrability in connection with larger scale, which ultimately is a function of increased risk, is another contributing factor in marine accidents [10].

The types of maritime accidents are;

* Groundings: vessel is in contact with the sea bed or an obstacle at the sea bed [11],

* Collisions: Any incident of two (or more) vessels striking each other on the water surface, regardless of the extent of damage,

* Fires and Explosions,

* Allisions: A running ships or vessels striking with a stationary object,

* Capsizing: Tilting over or turning upside down of a ship/vessel,

Due to this kind of accidents, approximately 5.74 million tons oil spills were reported from 1970 to 2017 (according to The International Tanker Owners Pollution Federation Limited (ITOPF) data

base). When we look over the last three decades, different surveys have identified the fact that the human element is the major cause of marine accidents. It means that human factor is of paramount importance for the safety at sea [12]. About 75-96% of marine accidents are caused, at least in part, by some form of human error. They specified that human errors contribute to 89-96% of collisions, 75% of explosions, 79% of groundings and 75% of allisions [13]. Appendix -1 shows a list of the accidents that have led to the largest (7000 tons or over) oil spills between 1967 and 2007. After 2007 ıt hasn't occurred any maritime accidents that have 7000 tons and over oil spills. The Figure-5 shows the distribution of causes that have resulted over 7000 tons oil spills according to Appendix

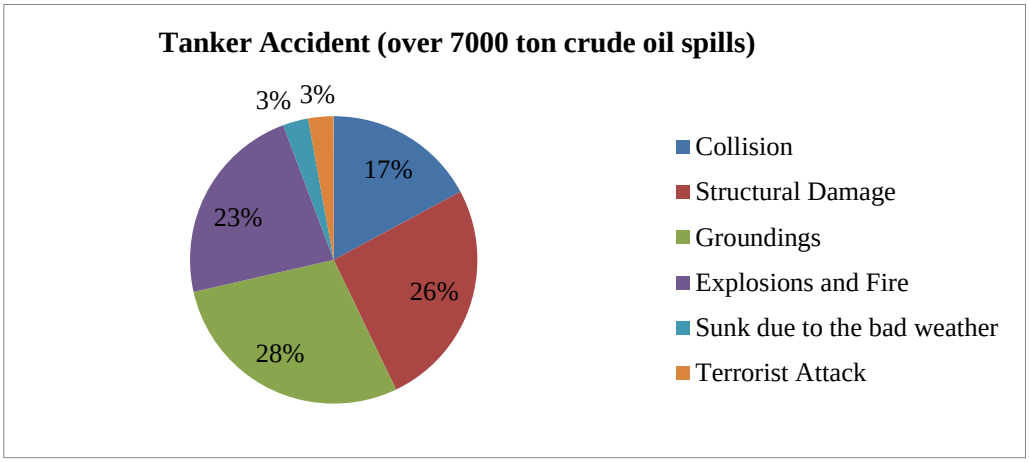

Figure-5: Tanker Accident (over 7000 tons oil spills)

Figure-5 is based on the ship accidents in which 7000 tons of oil spills. Here, the grounding appears to be at the highest level. Structural damage second and explosion and fire are followed by collision. In addition, Figure-6 is shows, what kind of accidents caused how much crude oil spill.

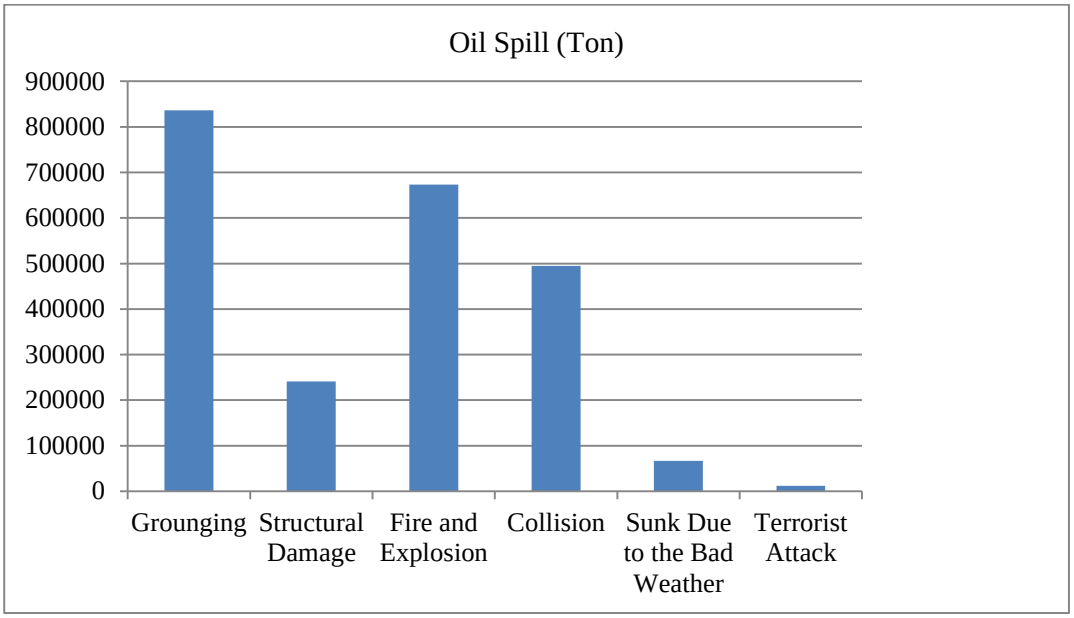

Figure-6 Type of accidents or events and amount of crude oil spills

As it can be seen in the graph; the highest level with 836100 tones oil spills is the grounding, explosion and fire are the second with 673000 tones oil spills and 494600 tons oil spills is collision is followed structural damage with 240700 tones oil spills.

The shipping industry has implemented a number of measures aimed at improving ships, port facilities and personnel safety. Despite all these measurements including new regulations and trainings, shipping accidents particularly collisions became the major type of maritime accidents [14]. Ships or other floating bodies are the main constituents of the collision cases. Such accidents have still been the bane of modern navigation - despite the sustained improvements in navigation techniques [6].

Their impacts on marine environment differ from one another. Shipwrecking with sinking especially on reefs in shallow water causes more severe damage to the environment. An accident by tanker or vessel carrying oil or other hazardous goods leaves indelible damage into the environment. In case such an accidents occurs close to a shore, miles of the coastline, reefs and other marine environment are intensively affected. Hazardous impact of an oil spill accident is numerous ranging from wildlife in the sea to fishing industry, human health and tourism.

The Liberian-flagged oil tanker Torrey Canyon oil spill on March 18, 1967 that was the first big tanker maritime accident. She ran onto rocks off the coast of Cornwall, England and 120000 tons of crude oil spilled at sea. As a result, oil pollution extended for a distance approximately; 120 miles along the Cornish Coast. The wind vector, coupled with the deflection of the coastline, caused the oil to spread along the coastline in substantial volume from almost 10 kilometres south of the site of the grounding to almost 200 km to the east. The Amaco Cadiz which is the most significant tanker accident ever to have occurred at the European seas is another example worth to mention. The accident occurred on March 17, 1978 in the Atlantic and caused spill of more than 230000 tons oil into the sea.

Another significant marine accident which was as devastating as Amco Cadiz for the environment occurred in the Pacific. That was Exxson Valdez. She departed the Alyeska Pipeline Terminal in Valdez, Alaska on Thursday evening, 23 March 1989, with just under roughly 206.683 ton of North Slope crude oil and was bound for Long Beach, California. Just after midnight on March 24 the vessel went hard aground on Bligh Reef. Four hours after the grounding, almost 2650 ton had been released [15]. The National Transportation Safety Board later estimated that by 6:00 a.m. on the morning of 24th of March, 34187 ton had been lost. Ultimately, the total amount of oil spilled was estimated to be 11 million gallons (41600 tons), It would be the largest oil spill into U.S. waters [15]. Sea otters, a species highly susceptible to oil-related mortality occupied the coastal waters were affected by the spill [16]. By September 1989, nearly 1,000 dead otters had been found in the spill area [17] and total immediate mortality due to the spill was likely higher, but difficult to quantify [18]. This massive 987-foot tanker has left a lingering, long-term effect on the natural habitat that surrounds these pristine waters, along with an enormous socio-economic effect that has left many people wondering when and where the next oil spill will be [19].

After grounding of The Exxon Valdez, the storm arrived in the region on 27 March 1989 and the oiling would extend nearly 700 miles through down the Alaska Peninsula, and the largest spill cleanup operation in history would peak at an estimated 10,000 workers, 1,000 vessels, 100 aircraft and helicopters, and extend into four years. After 25 years later of the accident Exxon Valdez in August 2013, a scientific research was done and there was found residual oil along the shorelines of Prince William Sound. It was not a large volume, relative to the amount spilled, but pockets of it are surprisingly unweathered, given the passage of a quarter century [15].

Other kinds of accidents that can occur on tanker or vessels carrying hazardous goods include; failures of equipment or engines, electrical faults and short circuits, leaks of oil or chemicals from the tanks and structural damages aboard. All of these kinds of accidents are considered to be caused by negligence such as; incorrect navigation, improper equipment, inadequate training of the vessel's crew, insufficient safety equipment or safety training, insufficient monitoring of the crew actions by supervisors, improper maintenance of the ship.

When a ship, especially a tanker or a vessel carrying oil or petroleum-derived products or hazardous chemical substances, is involved in an accident, the marine environment gets badly affected. The most

common types of accidents involving tankers or vessels carrying hazardous chemical substances are grounding in shallow waters colliding with other vessels or structures like bridges, and fires or explosions on board the ships like M/T “Indipendenta accidents in İstanbul Strait. It ıs another example of mass environmental disaster caused by a tanker accident in narrow waters on November 15, 1979. M/T “Indipendenta” with 94,000 tons of crude oil on board collided with the Greek vessel “Evrialy” at the southern entrance to Istanbul Strait. The collision caused a massive explosion and fire started onboard both ships. The cargo of crude oil leaked to the sea and dissolved in the water. Further explosions occurred on M/T “Indipendenta” resulting in further releases of oil to the sea and it continued burning until December, 14. It was estimated that 30.000 tons of crude oil burned and remaining 64.000 tons of cargo leaked into the sea [7]

Another dramatic accident Istanbul strait witnessed was M/T Nassia disaster. Which occurred very near to the entrance to the Black Sea. The Greek-flag M/T Nassia collided with the bulk carrier M/V Shipbroker on 13 March 1994. 27 people lost their lives and 9000 tons of petroleum was expelled to the sea and 20.000 tons burnt four days long affecting the marine environment severely [20]. Traffic at İstanbul Strait was suspended for several days. After this accident, the marine ecosystem was destroyed and all bays and beaches around were covered with oil and pitch. Major concerns were related to potential effects of spilled oil on trade, such as fisheries and aqua-culture products, and loss and/or change of habitats. Chronic long-term accumulation of hydrocarbons in coastal and estuarine waters and their contribution to a gradual change of ecological systems was an issue given the fact that oil products are significantly toxic and adversely influence the life activity of the benthos and total polyaromatic hydrocarbon concentration decreased gradually in seawater, but increased in sediments after the accident [21].

The main concern of transportation using tankers is the possibility of spills which will cause environmental disasters. Environmental disasters lead to death of both terrestrial animals and marine species and plants, as well as severe disruption of human lives. Moreover environmental disasters can have an effect on agriculture, biodiversity, economy, industrial activity, tourism and human health. Besides, oil spills have immediate impacts, such as contamination of benthic and zooplankton communities [22]. Besides, its impacts continue so long because of oil and its products are very toxic substances. They composed of hydrocarbons and it effects of marshlands and organisms at all levels of the food chain. Poisoning that can upset the balance of an ecosystem for decades to come [23]. Oil spills effect human life as well, both directly and indirectly. Many of the components of oil are toxic to humans [24]. Tourism and recreation along coastal areas diminish as well, causing significant harm to the economy of the region which is dependent on commercial fishing and tourism income.

4. Oil Pollution in Marine Environment

Oil pollution from ships was recognized as a problem after the industrial revolution. From that time to the Torrey Canyon disaster which occurred in 1967, there was no attempt to introduce effective measures concerning accidental and operational oil or other hazardous chemical substance pollutions.

The grounding and sinking of the Torrey Canyon off the Southwest coast of England, which ended up with spilling of 120.000 tons of oil into the sea, was the worst and biggest oil pollution ever at the time, and for the first time the general public were made aware of the dangers and profound consequences that the carriage of oil posed to the marine environment. Therefore, the Torrey Canyon incident has been the cornerstone for the protection of marine environment [6].

In the last decade there has been done tanker accident very rare. Also statistics show that the number of large oil spills caused by incidents has decreased over the years and no large spills were recorded in the last decade [25] but when the tanker accident does occur, its effect frequently has drastic consequences for the marine environment. The major effects of oil spills in marine environment as follows; pollution of the sea water, sea bed, mortality and infirmity of marine fauna (mammals/sea birds/shellfish etc.), shores and pollution of atmosphere (if the spilled oil burnt).

Crude oil is a mixture of hydrocarbons that exists as a liquid in underground geologic formations and remains a liquid when brought to the surface. Petroleum products are produced from the processing of crude oil and other liquids at petroleum refineries, from the extraction of liquid hydrocarbons at natural gas processing plants, and from the production of finished petroleum products at blending facilities [26]. Petroleum is a broad category that includes both crude oil which contain primarily carbon and hydrogen, but also but also contain smaller amounts of sulfur, oxygen, and nitrogen as well as metals such as nickel, vanadium, and iron [27] and petroleum products. The terms oil and petroleum are sometimes used interchangeably [26]. In the marine environment that hydrocarbons behaviours are depends on their density and solubility in water. The average density Crude oil and products display below the Table-1.

Table-1 Density of Crude Oil and Its Products [28]

Type	Average Density (g/cm^3)
Crude Oil	0.85
Heavy Crude Oil	0.94
Light Crude Oil	0.77
Fuel Oil	0.992

Sea water density is estimated 1.025 g/cm^3, this means that the lighter oil fractions rise to the sea water surface after the volatile constituents have evaporated, the heavy fractions sink to the sea bed from where some constituents may return to the surface after having been subjected to biological processes on the sea bed and the solubility of petroleum products in water is an important factor that affect their mobility and distribution within the environment [1].

When the oil spill onto the sea it suffuses the surface of the water, forming a film [29]. The inertia-gravity, viscous-gravity and viscous-surface tension stages are three stages of spreading [30] whereas advection depends on the activity of winds and sea currents [1]

On November 15, 1979 the Independenta tanker collided with M/V Evriali, The southern entrance of the Istanbul Strait Turkey, spilling its cargo 94000 crude oil into the sea and caught fire. It was the largest oil spill ever to occur in the region. The majority of oil was reported to have been consumed in the fire, contamination shorelines because of the current [31]. The spilling was drew away from the accident by the current action and affected the marine fauna in the region

Similarly, on March 24, 1989 The Exxon Valdez went hard aground on Bligh Reef, at the southern end of Valdez Narrows. The storm system that arrived in the region on March 27 spread what had been a fairly contiguous surface slick far and wide, thereby eliminating a necessary prerequisite for use of in-situ burning (i.e., a relatively thick and contiguous oil layer) and although another attempt was made on Tuesday, March 28, the oil had been mixed with water and no longer could be ignited. On Friday, March 31, Exxon declared that burning was no longer a viable response option [15]. The oiling would eventually extend nearly 700 miles through Prince William Sound and down the Alaska Peninsula the shoreline habitat and marine fauna in the Prince William Sound was impacted.

In the third example, carrying 252,000 tons of light crude oil caught fire about 70 miles north-west of Cape Town, South Africa on 6th August 1983. The Castillo De Bellver blazing ship drifted off shore and broke in two, approximately 160,000 tons of oil remaining in the stern section tanks - capsized and sank in deep water, 24 miles off the coast and the bow section was towed away from the coast and was eventually sunk with the use of controlled explosive charges 50-60,000 tons are estimated to have spilled into the sea or burned [32].

The fate of marine oil spills depends on the physical and chemical properties of oil, the characteristics of the environment affected, as well as the physical, chemical, and biological processes occurring there, such as evaporation, oxidation, dispersion, biodegradation, dissolution and interaction between oil and sediments [27]. The processes are known as “weathering”. Figure 7 demonstrates the kinds of processes that occur in the marine environment following an oil spill.

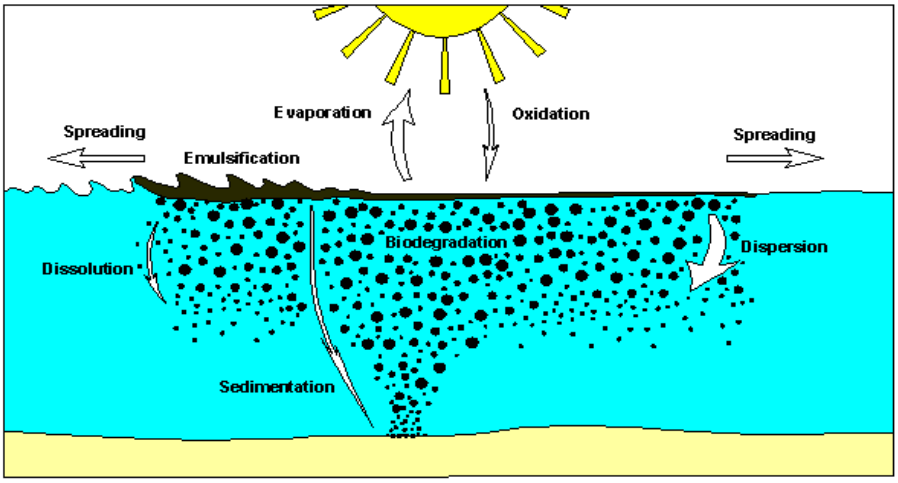

Figure-7: Fate of oil spilled at marine environment (weathering processes) [33]

Oil starts to spread out over the sea surface when it is spilled, initially as a single slick. The speed at which this takes place depends to a great extent upon the viscosity of the oil. Fluid, low viscosity oils spread more quickly than those with a high viscosity. After a few hours spilled oil will begin to break up and evaporate due to increased surface area of the slick, high temperature of weather, high winds speed, wave action and water turbulence, will then form narrow bands or windrows parallel to the wind direction.
Waves and turbulence at the sea surface can cause all or part of a slick to break up into fragments and droplets of varying sizes. This process is dispersion that it can be dispersed by a variety of natural processes; the influence of breaking waves is the dominant process. Breaking waves can split a slick into small droplets, facilitating oil mixing in the water column [34]. The density, viscosity and thickness of the oil spill, temperature of the weather and salinity of the sea water influence dispersion [35].

Another important process is emulsification. Emulsion is formed when two liquids combine, with one ending up suspended in the other. Emulsification of crude oils refers to the process whereby sea water droplets become suspended in the oil. This occurs by physical mixing promoted by turbulence at the sea surface. After Prestige accident approximately 60000 tons of emulsified oil was drove to the Spanish North West Coast by winds and sea current [36].

Other but less important process is dissolution. Dissolution water soluble compounds in an oil may dissolve into the surrounding water. This depends on the composition and state of the oil, and occurs most quickly when the oil is finely dispersed in the water column. However, these compounds are also those first to be lost through evaporation, a process which is 10-100 times faster than dissolution.

Oils react chemically with oxygen either breaking down into soluble products or forming persistent compounds called tars. This process is promoted by sunlight and the extent to which it occurs depends on the type of oil and the form in which it is exposed to sunlight and its radiation solar radiation can cause the photo-oxidation of oil components [37].

Sedimentation and sinking, some heavy refined products have densities greater than one and so will sink in fresh water. However sea water has a density of approximately 1.025 and very few crudes are dense enough or weather sufficiently, so that their residues will sink in the marine environment. Sinking usually occurs due to the adhesion of particles of sediment or organic matter to the oil. The interactions between oil and sediments are important, both as regard the behavior of the contamination and its removal [38]. Oil stranded on sandy shorelines often becomes mixed with sand and other sediments. If this mixture is subsequently washed off the beach back into the sea it may then sink. In addition, if the oil catches fire after it has been spilled, the residues that sometimes form can be sufficiently dense to sink.

The self-cleaning of sea water is biodegradation that is the most important of weathering process. Sea water contains a large variety micro-organisms or microbes that can partially or completely degrade oil to water soluble compounds that is considered to be one of the major removal mechanisms of organic contaminants [39].

Oil spills have short-term and long-term effects on marine environment. When the accident occurs the marine environments (marine fauna and marine flora) direct contact with spilled oil and it has devastating effects on marine environment due to has toxic substance. The impact of an oil spill on marine environment depends on wide range of factors. These include;

a. Type of oil spill and ıts quantity,
b. The rate of spread of the oil spill,
c. The location of the spill,
d. The time, season and weather conditions,
e. The properties, toxicity, and stability of the oil spill,
f. The species biodiversity at the site of the oil spill,
g. Environmental sensitivity, i.e., proximity of bird habitat, beaches, rocks, wetlands and the number and type of habitats.

When oil spills occur in the water, it forms a multimilimeter thick slick covering the water as a micro layer [40] and this slick hamper gas exchange with the air and limits penetration of solar radiation [41]. Therefore the rate of photosynthesis decrease and this aspect directly impact the rate of population of marine plants and organisms. In addition to this fish exposed to different ways of oil spill. Toxicity of the spill effects to their embryos and larvae. They may consume contaminated food and that impact food chain. Additionally marine mammals may effect oil spills of many ways. The sensitivity of mammals to spilled oil is highly variable [42]. Typical effects on marine habitats from toxicity to smothering display at below Figure 8.

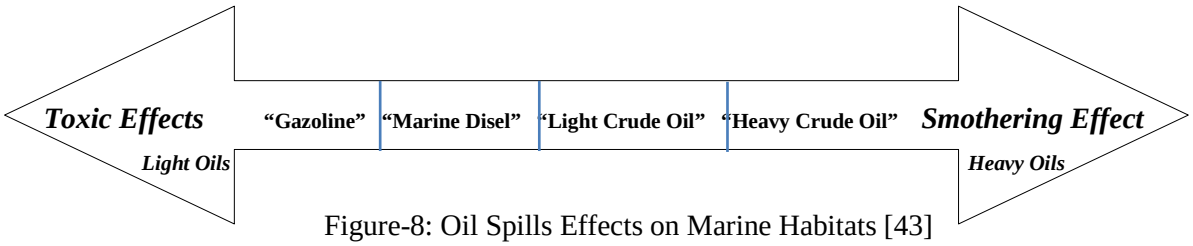

Figure-8: Oil Spills Effects on Marine Habitats [43]

A spill of a large quantity of highly dense oil, such as heavy crude oil or heavy fuel oil, has the potential to cause widespread damage in the tidal basin through smothering. However, toxic effects are less likely other highly viscous oil that has low water solubility, as the chemical components of the oil have a low biological availability. Oil incorporated within 'asphalt pavement' (a conglomerate of highly weathered oil and shingle) is similarly less bio-available, irrespective of its duration on the shoreline, although indirect damage may occur due to habitat modification. In contrast, the chemical components of gasoline or other oil light products have a higher biological availability and damage through toxicity is more [43] .

Especially the environmental pollution coming from the accident that the oil tankers are involved in is causing great damage both in the marine environment and the coastal areas. But, not only tankers pollute the environment, other sea vessels are also likely to have a major impact on the marine environment in the aftermath of any accident due to the large amount of fuel which is use for navigational purposes. An environmental pollution also affects the tourism and fisheries-dependent economy of the region negatively.

After tanker accidents, big environmental disasters could happen and international community realised that the environment. A consequence of oil spill is very complex and not limited in the area it occurred but in the whole region in the long term. Since an environmental awareness has long been raised in the world, when an accident occurs anywhere in the world, international community and organisations act shoulder to shoulder immediately to clean up the area.

As for the vessels involved in accidents, the extent of marine environment pollution resulting from a marine accident may increase due to the factors below;

- The quantity of oil or hazardous chemicals spilt,
- Behaviour of oil or hazardous chemical substances in the thalasso,
- Location of the accident or spill and environmental conditions and physical characteristics of the area,
- Seasonal and weather conditions,
- Water temperature, current direction and its speed.

Increasing extent of pollution will add the need for more human power and financial expense for cleaning. Therefore, selection of appropriate clean-up techniques and effectiveness is very important. Due to the biological composition of the affected environment, ecological importance of the component species and their sensitivity to oil pollution, the selected techniques of clean-up operations can also have a significant bearing on the effects of a spill [7]. . For instance; after the ‘Torrey Canyon' accident on 18 March 1967, due to opting for an inappropriate technique during the clean-up operations, which was the use of toxic cleaning agents on rocky shorelines, led to dramatic damage [43].

Although the detailed distribution of particular species present was altered and the effects of the perturbation could be traced over more than three decades, the overall functioning, biodiversity and productivity of the ecosystem was re-established within one or two years. Within this accident, marine life in the area of pollution almost disappeared. Most of fish plankton and small organisms were effected directly by oil pollution. The most detrimental environmental pollution in that case happened at the sea surface, sea bed, within the water column, and along the coast. Within a time span of several hours after the accident, the spilled oil was washed up onto the shores. The beaches, rocks, and coastal region were directly affected. It is well known that the petroleum residues from tanker operations, accidents, and other maritime sources continue to contaminate many coastlines and beaches worldwide [20].

5. Conclusion

There were numerous more accidents and collisions that affected marine environment drastically in the world. A great number of accidents resulting in oil spills and pollution with hazardous chemical substances occurred in the past and caused substantial damage to the marine environment and human life. The analysis shows that Europe records the highest volume of spills and hazardous chemical substance pollutions. However, overall volume of each spill is decreasing from past decades to the present.

Marine accidents are crucial for these aspects; human lives, marine environment, trading and financial losses. Not only maritime accidents, but also ship’s bilge water, ballast water, discharging sewage/waste water, ammunition and industrial waste (deep-sea disposal) spilled into the sea cause

environmental and marine pollution. In sum, ship-generated “environmental disasters” damage sea bed, sea surface and habitat and harm the survival of marine/coastal flora and fauna, cause serious distress to marine ecosystems and affect people’s livelihoods and impair the quality of life. Marine environment and coastal areas are still under the threat of ship-induced pollution. Though many nations worldwide have enacted legislation or have been the party of some protocols, agreements, and conventions related with marine accidents and pollution, the number of accident and incidents have been gradually decreasing, marine environment is still being polluted more or less by ships around the world. Some of the cases are the result of human errors and the ship’s structural defects, whereas some of them are the outcome of physical factors

- Within this scope, in order to avoid maritime accidents and reduce the extent of pollution, the following measures should be taken; improving ship standards,
- Improving training facilities to obtain qualified seaman power,
- Enhancement of consideration for ship agents and seafarers
- Implementation and strict control of regulations and agreement,
- Enhancement of cooperation between the maritime authorities and other parties by governments.

Oil spills impact on the marine environment depends on numerous factors, such as; the physicochemical parameters of the oil, the characteristics of the environment affected, and weathering processes; such as evaporation, dissolution, dispersion, emulsification, oxidation, biodegradation, and sedimentation. Oil spills endanger to marine fauna and flora and cause damage to sea and shores ecosystems. Many of the petroleum-related chemicals that are spilled are toxic and carcinogenic. This toxic chemical structure of oils affect the marine food chain from phytoplankton to fish, then to other sea creatures and finally to human.

In addition, oil and its derivatives or products can be accumulated and immobilized in the sea bed for long periods. Oil spills are especially dangerous when they occur in small inland seas like Marmara Sea or straits like Turkish Straits that have heavy sea traffic.

Appendix

Summary of Spills (over 7000 tons) [44]

Nr.	Date	Ship Name	Ship Length (m)	Ship Built Date	Oil Spill Amount and Nature (tons)	Location	Incident Details and Lost of Life
1	18 March 1967	Torrey Canyon	297.03	1959	120000 Crude Oil	Pollard's Rock on Seven Stones reef between the Cornish mainland and the Scilly Isles/England	Grounding and Sinking, due to a navigational error
2	14 January 1970	Al Bacruz [45]	172.5	1954	20400 Crude Oil	300 nautical miles east of Azores, Portugal	Structural damage, this caused the vessel to sink
3	5 May 1970	Polycommander	217.84	1965	15000 Light Crude Oil	Vigo, Galicia/Spain	Grounded on a reef while attempting to enter the port
4	7 October 1970	Anastasia J.L.	N/A	1952	18500 Crude Oil	360 nautical miles off the coast of Azores/Portugal	Ship Structural damage due to weather condition
5	01 April 1972	Giuseppe Giuletti [46]	192.2	1954	26,000 Disel and Fuel Oil	Cape St. Vincent/ Portugal	Ship Structural damage, this caused the vessel to sink
6	5 November 1973	Golar Patricia	327.1	1969	10000 Bunker Oil	130 miles off the Canary Islands/Spain	Explosions, during the tank cleanings and sank 43 died
7	29 January 1975	Jakob Maersk [47]	261.8	1966	80000 Crude Oil	Porto/Portugal	Grounding exploding and fire
8	14th July 1975	Princess Anne Marie [48]	235	1964	14800 Crude Oil	300 nautical miles off the coast of Australia	Structural damage
9	12 November 1975	Olympic Alliance	324.43	1970	10000 Light Crude Oil	Dover Strait	Collided with Royal Navy Frigate HMS Achilles
10	12 May 1976	Urquiola	276.54	1973	101000 Crude Oil	La Coruña/Spain	Grounding

11	18 January 1977	Irenes Challenge	193.65	1956	34000 Light Crude Oil	Midway Islands/Japan	Ship Structural damage, this caused the vessel to sink
12	16 March 1978	Amoco Cadiz	334	1974	227000 Crude Oil	Portsall Rocks/France	Grounding, owing to failure of her steering mechanism
13	31 December 1978	Andros Patria	323.71	1970	60000 Heavy Crude Oil	Off the coast of La Coruna, Galicia/Spain	Explosion and fire 34 died
14	8 January 1979	Betelgeuse	281.64	1968	40000 Crude Oil	Whiddy Island in Bantry Bay Port Ireland	Explosions and fire 49 died
15	19 July 1979	Atlantic Empress & Aegean Captain	347	1974	276000 Crude Oil	Caribbean Sea, off Tobago island	Collided with Aegean Captain 26 died
16	15 November 1979	The Independenta	283	1978	94000 Crude Oil	The southern entrance of the Istanbul Strait Turkey	Collided with M/V Evriali 43 died
17	06 August 1983	Castillo de Bellver	334.02	1978	160000 Light Crude Oil	64 km off Table Bay South Africa	Explosion and fire
18	10 November 1988	Odyssey [49]	275	1971	132000 Crude Oil	Nova Scotia/Canada	Explosion, fire and sunk 27 died
19	23 March 1989	Exxon Valdez	300.85	1986	41600 Crude Oil	Prince William Sound Alaska/Canada	Grounding
20	19 December 1989	Khark [50]	339.6	1975	70000 Heavy Crude Oil	400 nautical miles North of Las Palmas The Canary Islands	Explosion and fire
21	26 December 1989	Aragon	321.6	1976	25000 Crude Oil	33 nautical miles off Madeira Island Portugal	Structural damage

22	11 April 1991	Haven	334	1973	144000 Crude Oil	Off the coast of Genoa/Italy	Fire and explosion
23	28 May 1991	ABT Summer	344.43	1974	57000 Heavy Crude Oil	800 nautical mile off the coast of Angola	Fire and Explosion 1 died
24	21 July 1991	Kirki	265.69	1969	18000 Crude Oil	55 nautical miles off the coast of Cervantes in Western Australia	Structural damage and fire due to bad weather
25	3 December 1992	Aegean Sea	261.02	1973	67000 Light Crude Oil	La Coruna/Spain	Grounding
26	16 April 1992	Katina P	238	1966	66700 Crude Oil	Maputo Bay/ Mozambique	Sank due to bad weather condition
27	05 January 1993	Braer	241.51	1975	84500 Crude Oil	Southern tip of the Shetlands/Scotland	Grounding due to bad weather conditions
28	13 March 1994	Nassia	276.51	1976	95000 Crude Oil	Istanbul Strait Turkey	Collision with Cargo ship Shipbroker 26 died
29	15 January 1996	Sea Empress	274.30	1993	73000 Light Crude Oil	Milford Haven Passage/England	Grounding
30	11 December 1999	Erika	184	1975	20,000 Heavy Fuel Oil 6	Off the Bay of Biscay	Structural damage
31	06 October 2002	Limburg [51]	332	2000	12000 Heavy Crude Oil	3 nautical miles from Ash-Shihir Port Yemen	Terrorist attack, hit by explosives from a small craft
32	13 November 2002	Prestige	243.5	1976	64000 Heavy Fuel Oil 2	Off Cape Finistere Galicia/Spain	Structural damage due to bad weather conditions

33	27 July 2003	Tasman Spirit	236.86	1979	27000 Crude Oil	Outside Karachi Harbour/Pakistan	Grounding
34	14 December 2004	Al Samidoun [52]	322	1992	8600 Heavy Crude Oil	Suez Channel, near Ismailia/Egypt	Collision with a dredger or wharf
35	7 December 2007	Hebei Spirit	338	1993	11000 Heavy Crude Oil	Port of Incheon Republic of Korea	Collision with the barge Samsung 1 died

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