



From Gases and Evaporators risk assessment towards an Integrated management of sea and land pollution incidents

MANIFESTS is a project co-funded by the European Union Civil Protection - DG-ECHO, developed in cooperation with RBINS, CETMAR, IMT Mines Alés, INTECMAR, IST, the UK Security Agency as associated partner and coordinated by Cedre.



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Lessons learnt on past accidents involving ammonia, methanol, LNG and Li-ion batteries

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General introduction

The share of global transport by sea is expected to double by 2050, and represented 1 076 million tonnes of CO₂ in 2018, being responsible for around 2.9% of global emissions caused by human activities [1]. In response to that, the International Maritime Organization and the European Commission clearly stated their intention to reduce the Greenhouse Gas (GHG) emissions from maritime transport. The 2023 IMO Strategy on Reduction of GHG Emissions from Ships was adopted in July 2023, setting out the levels of ambition to reduce GHG emissions and guiding principles. The 2023 IMO GHG Strategy includes, in particular, a new level of ambition regarding to the use of zero or near-zero GHG emission fuels and/or energy sources which should represent at least 5%, with a target of 10%, of the energy used by international shipping by 2030. Ammonia, methanol, liquified natural gas (LNG) and lithium-ion batteries (LIBs) are potential energy sources to be used in maritime transport. Potential technologies and improvements are currently being developed, but less is understood about the associated risks they pose in case of accidents.

As part of the MANIFESTS *Genius* (from Gases and Evaporators risk assessment towards an Integrated management of sea and land pollution incidentS) project, a literature review was carried out on past accidents involving ammonia, methanol, LNG or lithium-ion batteries, in order to draw lessons from the past to improve preparedness and potential crisis management. The review is separated into four different chapters.

The first chapter of the review focuses on accidents that involved ammonia on the coast of Galicia, Spain. Then, accidents involving methanol on a global scale are presented, followed by the ones involving LNG. The last part of the review focuses on the accidents due to Lithium-ion batteries in the maritime industry. Each part of the review investigated the evidence around the maritime incidents and their potential to impact public health. The properties and characteristics of each propulsion energy studied are also given in the corresponding section, along with recommendations for better risk management. Key points of each chapter are summarised below.

1st Chapter: Lessons learnt on past accidents involving **ammonia** in coastal areas in Galicia, Spain

- Ammonia accidents are not frequent on the Galician coast, but always represent a significant risk to human health and the environment.
- Information sources are very scarce as there is no official record, as well as no records on the medium and long-term consequences.
- Evidence of improved safety practices, continuous monitoring, and better training was reported. Improvement was also achieved thanks to efficient early warning systems in industrial and fishing facilities.



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2nd Chapter: Lessons learnt on past accidents involving **methanol**

- Most of methanol accidents involved fires/explosions, with some deadly fires due to diverse ignition sources: mechanical ones, lightning strikes, handling operations.
- Persisting lack of investigation and knowledge sharing over the years: need of detailed post-accident surveys, better investigation of ignition sources.
- Environmental contamination happened due to delay of response establishment, and some responses were ineffective because not suitable. Better Contingency Plans and suitable training are required.

[1] https://climate.ec.europa.eu/eu-action/transport/reducing-emissions-shipping-sector_en

3rd Chapter: Lessons learnt on past accidents involving **liquified natural gas (LNG)**

- With regard to LNG carriers and transportation of LNG by pipeline, serious incidents are very rare.
- Accidents involving LNG releases at terminals have resulted in serious accidents with important death tolls.
- LNG remains a high hazard substance and suitable control is not fully achieved. Full understanding of scenarios and impacts is still needed to improve the safety procedures and systems as well as the risk assessment.
- High importance of surveillance and security measures within the current geopolitical context and tension surrounding energy issues.

4th Chapter: Developing the Evidence Base for Public Health Risks from **lithium batteries** in the Maritime Industry

- Only few incidents reported to date, but presence of an upwards trend possibly reflecting the increasing occurrence of LIBs as both cargo and propulsion methods.
- Instability of LIBs can lead to fire and explosion as well as significant release of toxic chemicals. Several causes of instability were defined: age and condition of LIBs, level of charge, damage, storage, temperature, humidity and salt water.
- LIB fires pose severe challenges to conventional firefighting techniques and have already proved fatal to crews and responders.
- Need to inform and train public health responders to be aware of the potential health impacts or delayed effects of gas exposure, making sure that passengers are registered and followed up if necessary.



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Lessons learnt on past accidents involving Ammonia in coastal areas in Galicia (Spain) 30/01/2025

Work Package 3: CROSS-BORDER/LAND-SEA PREPAREDNESS
AND RESPONSE TO INCIDENTS INVOLVING
AMMONIA / LNG / LITHIUM ION BATTERIES

Task 3.1 PAST INCIDENTS REVIEW

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Table of contents

1. Background.....	3
1.1. Context and MANIFESTS-Genius project objective	3
1.2. The use of Ammonia in Galicia.....	3
2. Incidents involving Ammonia in Galicia.....	5
2.1. Fergofrío	6
2.2. Congeladora Coruñesa	6
2.3. Fandicosta	7
2.4. Leiro e Hijos	8
2.5. Conservera Leiro	8
2.6. Carnicería San Cibrao	9
2.7. Conservera Jealsa	9
2.8. Fish market	10
2.9. Canning factory.....	11
2.10. Fish farm.....	11
2.11. Estrella Galicia	12
2.12. Albacora cuatro.....	12
3. Conclusion.....	13



1. Background

1.1. Context and MANIFESTS-Genius project objective

Anhydrous ammonia is widely used as a refrigerant gas in many industrial plants, especially by industries in charge of the preservation of sea products (fishing, aquaculture...) which are generally located on the coast. Also, freezer vessels use this substance as refrigerant. Facilities located on the coast with ammonia-based industrial refrigeration systems have the potential to release toxic ammonia gas during an incident and many examples of this can be found in reported literature. Similar events can also arise from vessels using ammonia as refrigerant or as a fuel and related port storage facilities. Such a release can put not only the workers at risk but can also impact the wider local population.

These facilities (industries/storage tanks/vessels) may be subjected to accidents resulting in the release of this highly toxic gas with potential to impact workers and surrounding communities including transboundary.

Based upon the success of MANIFESTS, the **MANIFESTS-Genius** (From **G**ases and **E**vaporators risk assessment towards an **I**ntegrated management of sea and land pollution incidents) project aims to strengthen preparedness and response capabilities for integrated management of coastal marine pollution by gases or evaporators, both at sea and on the shoreline. Specifically, WP3 aims to review past incidents in order to better known real incidents scenarios. This information will be used to build up hypothetical scenarios for desktop exercises where different aspects will be considered as information sharing among marine pollution authorities and response groups from different agencies/organisms with responsibilities during an incident near the shoreline to enhance efficient coordination of the land and sea response.

1.2. The use of Ammonia in Galicia

Ammonia is a clear colourless gas with a strong odour. Although gas is lighter than air, vapours from a leak initially hug the ground. Long-term inhalation of low concentrations of the vapours or short-term inhalation of high concentrations has adverse health effects. Ammonia is highly soluble in water, but it can be released into the atmosphere depending on pH and temperature: Ammonia is rapidly ionized in water, but in alkaline seawater (~pH 8.1), a significant fraction remains in non-ionized form, making it easy to volatilize into the atmosphere. The non-ionized form is highly toxic for marine life.



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The use of ammonia in freezing plants and the fish industry in Galicia is quite common due to its properties as a refrigerant, making it ideal for maintaining the very low temperatures required in processing and preserving fish products. Ammonia (NH₃) is a natural refrigerant that offers several advantages but also presents certain risks that need to be managed properly. The use of ammonia in refrigeration systems within the food industry is quite common, especially in industrial and large-scale facilities.

Some of the advantages of Ammonia as a refrigerant are:

- **Energy Efficiency:** Ammonia has a high heat absorption capacity, making it an efficient refrigerant. This allows refrigeration systems using ammonia to consume less energy.
- **Low Cost:** Compared to other synthetic refrigerants, ammonia is relatively inexpensive, reducing maintenance and operational costs.
- **Sustainability:** Unlike many synthetic refrigerants, ammonia does not contribute to global warming or have a high ozone depletion potential. Additionally, it is a natural refrigerant that breaks down easily in the atmosphere.
- **High Thermal Performance:** Ammonia has excellent thermal conductivity, which improves heat transfer efficiency.

And some of the disadvantages and risks that the use of Ammonia has are:

- **Toxicity and Risk of Leaks:** Ammonia is toxic, so leaks can be dangerous for both workers and the environment. In the case of significant leakage, it can damage respiratory systems and general health.
- **Flammability:** Although ammonia itself is not flammable, under certain temperature and pressure conditions, it can form flammable mixtures with air at very high concentrations.
- **Corrosiveness:** Ammonia can be corrosive to certain materials if it comes into direct contact, so proper materials must be used for piping and system components.

Ammonia is particularly useful in food businesses because of its ability to maintain extremely low temperatures, which is essential for preserving perishable products, such as:

- **Meats and Fish:** In processing plants, ammonia is used to maintain very low temperatures during production and storage.
- **Dairy Products:** To preserve milk and fresh dairy products.



- Fruits and Vegetables: In refrigeration systems for storage rooms and conservation chambers.
- Freezing: In industrial quick-freezing systems.

Galicia, with its extensive coastline and a significant fishing industry, has numerous plants that use ammonia in their refrigeration systems. Plants that process fish, such as freezing and storage facilities, require very low temperatures to preserve the freshness of the products. Ammonia is one of the most used refrigerants in these facilities due to its high energy efficiency and its ability to maintain extremely cold temperatures, which are necessary for quickly freezing fish and ensuring long-term preservation.

Some of the key areas where this technology is found include the area of Vigo that is one of the main fishing ports in Galicia, with numerous plants dedicated to processing and freezing fish and seafood. Some of these facilities use ammonia in their refrigeration systems due to the need to maintain products like hake, tuna, and other fish at very low temperatures. Other areas as Ría de Arousa where many freezing fish and canning plants are located, such as those processing tuna, sardines and mussels, also require ammonia refrigeration systems to keep the fish fresh during their process. Many other areas as fishing ports located along the coast of Galicia have refrigeration facilities that use ammonia to maintain the cold chain for the fish arriving directly from fishing boats.

By other hand, several companies on the coast of Galicia are involved in the production and use of ammonia, especially in the context of energy transition and decarbonization. Such is the case of IGNIS, that through its subsidiary Ammonia Green Galicia, is developing a green ammonia plant at the Outer Port of A Coruña, in Punta Langosteira. This project aims to produce and export green ammonia, using renewable hydrogen and nitrogen from the air. The plant is expected to start operations in 2026. Although not directly on the Galician coast, the Bahía H2 Offshore project, located at the port of Santander, has implications for the region. This project aims to transform offshore wind energy into green hydrogen and ammonia, with the participation of companies such as Fertiberia, Repsol, Navantia, and Enagás.

It is important to note that while some of these initiatives are in the planning or construction phases, they reflect the interest and investment in green ammonia production in the region. These companies are contributing to the energy transition and the development of sustainable technologies in Galicia.

2. Incidents involving Ammonia in Galicia



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Accidents involving ammonia on the coast of Galicia, while not frequent, have produced several situations that due to its toxicity and the risks associated with its handling could have had serious consequences. While specific details about each incident are not available, fish freezing plants on the Galician coast, particularly in Vigo and A Coruña, have faced accidents related to ammonia leaks in their refrigeration systems. These incidents were caused by failures in valves, pipes, or refrigeration equipment, resulting in exposure to hazardous ammonia levels as they led to the release of ammonia gas into the air.

In the absence of official records, the only source of information has been the news published in various media outlets. Some of the most relevant incidents in the last decades include:

2.1. Fergofrío

Fergofrío	
Date	13/08/2006
Location	Fergofrío warehouse, Porto de Vigo, Vigo, Pontevedra
Product/Amount	Ammonia/ not known
Cause	Burst of one of the safety valves
Impacto on health	Not detected
Impacto on environment	Not detected
Response	Vigo Firefighters intervention. The incident happened at night. Evacuation not mentioned.
Consequences	Temporary closure of the facilities
Source	https://www.lavozdeg Galicia.es/noticia/vigo/vigo/2006/08/14/industria-frio-origina-cinco-fugas-amoniaco-ano/0003_5023678.htm

2.2. Congeladora Coruñesa

Congeladora Coruñesa



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Date	11/03/2009
Location	Freezing warehouse, A Pasaxe, A Coruña
Product/Amount	Ammonia/300 liters
Cause	Breakage of a valve in the cooling system
Impacto on health	Around one hundred people evacuated/ no affection declared
Impacto on environment	Not detected
Response	Coruña Firefighters intervention controlling toxic cloud/ staff from the company/ Civil protection department involved in the evacuation of people
Consequences	Opening of disciplinary proceedings due to repeated incidents
Source	https://www.europapress.es/galicia/noticia-conselleria-industria-abre-expediente-informativo-escape-amoniaco-empresa-coruna-20090312134059.html

2.3. Fandicosta

Fandicosta	
Date	09/05/2009
Location	Fishing processing facility, Domaio, Moaña, Pontevedra
Product/Amount	Ammonia/
Cause	Fire in one of the company's warehouses
Impacto on health	The burning of chemicals and insulation material caused a thick cloud of toxic smoke, so the population near the factory was confined to their homes for several hours and the main road was closed to traffic.
Impacto on environment	Aquaculture areas were closed as a precaution. The analyses carried out did not show any impact on commercial species.
Response	Firefighters from the regional fire stations of O Morrazo, A Louriña and Vigo, as well as agents from the Moaña Local Police and Civil Protection from Cangas. The fire was also fought from the sea under the coordination of Galician Coastguards.
Consequences	The company estimates the losses, in machinery alone, between 14 and 18 million euros due to the fire that destroyed 60% of the company's facilities and estimates that around 8,000



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	tons of fish were burned.
Source	https://www.lavozdeg Galicia.es/noticia/vigo/moana/2016/05/09/declarado-incendio-naves-fandicosta-moana/00031462812545610569403.htm https://www.lavozdeg Galicia.es/noticia/vigo/moana/2016/05/10/incendio-fandicosta-da-extinguido-16-horas-despues-iniciarse/00031462868080715346674.htm https://www.lavozdeg Galicia.es/video/galicia/2016/05/10/nivel-alerta-decretado-incendio-fandicosta-excepcional/0031_2016054887137017001.htm

2.4. Leiro e Hijos

Leiro e Hijos, Portonovo	
Date	25/08/2009
Location	Seafood stew factory, Portonovo, Pontevedra
Product/Amount	Ammonia/unknown
Cause	The incident occurred in the compressor room, when the filter of one of the tanks was being changed.
Impacto on health	It caused the evacuation of the workers and the admission of one of them to a hospital
Impacto on environment	Not detected
Response	Salnés Firefighters
Consequences	Not reported
Source	https://www.diariodepontevedra.es/articulo/galicia/una-fuga-de-amoniaco-provoca-el-desalojo-de-un-cocedero-de-marisco-en-portonovo/20090826225900174057.html

2.5. Conservera Leiro

Conservera Leiro	
Date	04/05/2017
Location	Freezing warehouse, Adina, Sanxenxo, Pontevedra
Product/Amou	Ammonia/not kown



nt	
Cause	Technical failure
Impacto on health	Not detected
Impacto on environment	Not detected
Response	Local Emergency Service of Sanxenxo, of the Provincial Firefighters Consortium and company technicians.
Consequences	Not reported
Source	https://www.lavozdeg Galicia.es/noticia/pontevedra/sanxenxo/2016/12/05/posible-fuga-amoniaco-conservera-activa-personal-emergencias/0003_201612P5C3994.htm

2.6. Carnicería San Cibrao

Carnicería San Cibrao	
Date	25/06/2020
Location	Abandoned meat processing facility, San Cibrao, Lugo
Product/Amount	Ammonia/Pressurized ammonia bottle
Cause	Deteriorated container in abandoned facilities
Impacto on health	Not detected/ As preventive measure the population near the factory was confined to their homes
Impacto on environment	Not detected
Response	Local Emergency Service of San Cibrao, Police and private company for waste treatment.
Consequences	Not reported
Source	https://www.elprogreso.es/articulo/a-marina/retirado-botellon-gas-amoniaco-causo-fuga-alarma-san-cibrao/202007091413131448565.html

2.7. Conservera Jealsa



AMMONIA INCIDENTS REVIEW IN COASTAL AREAS GALICIA

25/02/2025

Conserva Jealsa	
Date	8/05/2021
Location	Canning factory, Boiro, A Coruña.
Product/Amount	Ammonia/None
Cause	Fire in the facilities without leaking. The main concern is that the fire does not reach the ammonia tanks.
Impact on health	Not detected
Impact on environment	Not detected
Response	Firefighters, Galician Emergency Agency, Spanish and Galician Coastguards.
Consequences	Not reported
Source	https://www.lavozdeg Galicia.es/noticia/barbanza/boiro/2021/05/08/incedio-jealsa-moviliza-amplio-despliegue/00031620478183572545683.htm

2.8. Fish market

Port fish market Viveiro	
Date	12/04/2022
Location	Cold room in the Port fish market, Viveiro, Lugo
Product/Amount	Ammonia/Unknown
Cause	Leak of unknown quantity from a pipe
Impact on health	Not detected
Impact on environment	Not detected
Response	Local Emergency Service of Viveiro, Police and local Civil Protection crew.
Consequences	Not reported
Source	https://www.elprogreso.es/articulo/a-marina/retirado-botellon-gas-amoniaco-causo-fuga-alarma-san-cibrao/202007091413131448565.html



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2.9. Canning factory

Canning factory Boiro	
Date	01/08/2022
Location	Canning factory, Boiro, A Coruña.
Product/Amount	Ammonia/Unknown
Cause	Ammonia leak in the valve of a canning factory's refrigeration system. The safety valve of the cooling system, located on the same roof of the building, blew due to pressure, possibly due to the high temperatures reached.
Impacto on health	It caused discomfort to several people, although none of them have needed medical assistance.
Impacto on environment	Not detected
Response	Firefighters, local police and Galician and national coastguards.
Consequences	Not reported
Source	https://www.europapress.es/galicia/noticia-fuga-amoniaco-conservera-boiro-coruna-provoca-malestar-varias-personas-necesitar-asistencia-20220801195211.html

2.10. Fish farm

Fish farm, Xove	
Date	12/08/2022
Location	Fish farm, Xove, Lugo.
Product/Amount	Ammonia/Unknown
Cause	The failure of a valve in the cold room of a fish farm on the coast.
Impacto on health	Not detected
Impacto on environment	Not detected



AMMONIA INCIDENTS REVIEW IN COASTAL AREAS GALICIA

25/02/2025

Response	Firefighters of Viveiro and emergency response group of Cervo. Control through water curtain.
Consequences	Not reported
Source	https://www.galiciapress.es/articulo/lugo/2022-08-13/3856099-controlada-fuga-amoniaco-fabrica-xove-lugo https://www.lavozdeg Galicia.es/noticia/somosmar/acuicultura/2022/08/13/amplio-dispositivo-seguridad-fuga-amoniaco-empresa-xove/00031660372370382649549.htm

2.11. Estrella Galicia

Estrella Galicia, A Coruña	
Date	29/08/2024
Location	Beer brewery, A Coruña.
Product/Amount	Ammonia/Unknown
Cause	The failure on the engine room.
Impacto on health	Not detected/ Factory staff evacuated.
Impacto on environment	Not detected
Response	Firefighters of Coruña and Emergency Health Service of Galicia-061, the National and Local Police and the Civil Protection Volunteer Group of A Coruña.
Consequences	Not reported
Source	https://www.lavozdeg Galicia.es/noticia/coruna/2024/08/29/desalojan-plantilla-estrella-galicia-madrugada-fuga-amoniaco/00031724915367555496774.htm

2.12. Albacora cuatro

This accident is included in this list because although it occurred in Seychelles, the boat was Galician, and it is an example that could be repeated on any boat that was in Galicia.



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Albacora Cuatro	
Date	15/06/2022
Location	Galician tuna fishing boat. Puerto Victoria, Seychelles island.
Product/Amount	Ammonia/Unknown
Cause	During work on replacing a seal on the fish cooling circuit on the lower deck, a leak occurred.
Impacto on health	There were 2 casualties, 8 injured: 2 mechanics lost their lives and eight sailors were also injured by inhalation of ammonia,
Impacto on environment	Not detected
Response	Seychelles emergency services.
Consequences	Not reported
Source	https://www.lavozdeg Galicia.es/noticia/somosmar/2022/06/16/tripulantes-albacora-cuatro-murieron-intoxicados-amoniaco/00031655406893366894716.htm

3. Conclusion

While ammonia accidents on the Galician coast are not frequent, they always represent a significant risk to human health and the environment.

One of the main problems when collecting information on accidents that have occurred in the region is that the sources of information are very scarce, there is no official record. In addition, there are no records on the medium and long-term consequences of the incidents, or the measures taken to prevent their recurrence.

This lack of official records of this type of incident means that the information available is biased only towards those incidents that have social repercussions. It is estimated that the number of incidents is greater than that included in this report, since those that are not of great magnitude or that have not had visible consequences for the population are not included.

It is advisable to have a record of this type of incident that includes the actions carried out and allows for improved control and prevention systems, especially in the case of small and medium-sized companies.



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Nevertheless, authorities and industry companies have focused on improving safety practices, continuous monitoring, and training to prevent these accidents and minimize their consequences. The implementation of advanced refrigeration technologies and early warning systems also helps mitigate the risks of leaks and accidents in industrial and fishing facilities in the region.



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Lessons learnt on past accidents involving Methanol

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Lessons learnt on past accidents involving Methanol

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Lessons learnt on past accidents involving Methanol

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Table of contents

SUMMARY.....	4
1. Introduction.....	5
1.1. Background.....	5
1.2. Aims and Objectives.....	5
2. Methanol.....	6
2.1. Chemical properties.....	6
2.2. Health hazards.....	7
3. Description of past accidents.....	8
3.1. Kanawha River, 1960.....	8
3.2. Westward, 1980.....	9
3.3. Iver Heron, 1988.....	9
3.4. Maasgusar, 1989.....	10
3.5. Wilmington, 1992.....	10
3.6. Frankfurt am Main, 1993.....	11
3.7. Map Ta Phut, 1995.....	12
3.8. MV Floreana, 1998.....	12
3.9. Perla, 2004.....	13
3.10. Vincuña, 2004.....	13
3.11. Metanol, 2005.....	14
3.12. Slave Lake, 2006.....	15
3.13. Safmarine Leman, 2006.....	16
3.14. Barrel lost at sea, 2007.....	16
3.15. Clamecy, 2010.....	17
3.16. Bunga Alpina, 2012.....	17
3.17. Rotterdam, 2016.....	18
3.18. Tasman Sea, 2017.....	19
3.19. Loss of storage containers, 2017.....	19
3.20. Ohio River, 2018.....	20
3.21. National Automotive Chemical, 2021.....	20
3.22. Ohio river, 2023.....	21
4. Conclusion and recommendations.....	23

SUMMARY

- The use of methanol as an alternative fuel is growing towards the decarbonisation of the marine industry. Hence, the large-scale transport and storage of this chemical is also expected to increase.
- As being a toxic and highly flammable compound, methanol can lead to tragic accidents, either during its handling or transport. As part of the MANIFESTS Genius project, a review of marine incidents involving methanol was carried out. The potential public health risks associated with these incidents were highlighted, and the response measures implemented in each case were described.
- The number of accidents reported in this review was relatively low for the broad period of time considered, and most of the accidents involved fires rather than spills.
- Delays and inefficiencies in response actions were noted, highlighting the importance of local Contingency Plans and cooperative training. Additionally, the lack of investigation into causes of the accidents emphasizes the need for detailed post-accident documentation and knowledge sharing.
- In light of these findings, there is a need for improved fire prevention, more frequent inspections of equipment, and better response planning towards environmental contamination. These insights are crucial for enhancing safety in maritime methanol transport.

1. Introduction

1.1. Background

As the international maritime organization (IMO) adopted a strategy for reducing the emissions of greenhouse gas from ships, the transition to using alternative fuels has become a realistic need for many shipping companies. Methanol is one of the feasible alternative candidates to replace fossil fuels on board ships. Nevertheless, methanol is also toxic to humans and highly flammable. An exponential growth in the demand for methanol was already expected in a 1999 review prepared for the American Methanol Institute¹. As demand for methanol grows, barge and rail transport as well as storage and distribution facilities will expand, increasing the risk of accidental releases into the environment and accidents that could pose a threat to public health.

1.2. Aims and Objectives

As part of the MANIFESTS *Genius* project Work Package 3, task T3.1, this review aims at examining past maritime incidents involving methanol: volume spilt, intervention responses, impacts on health and environment. Incidents that occurred on land with potential discharge into the aquatic environment were also taken into account. The responses and actions established by the different authorities at stakes were highlighted. By providing a description of these past accidents, this study aims at sharing knowledge to better answer to potential future accident scenarios. Learning from what happened in the past is of crucial importance to better handle any large-scale chemical release that could prove harmful to humans and to the environment.

Thus, the following aspects were investigated:

- Description of the accident, sequence of events
- The responses and actions taken
- The decision-making and collaborative processes used to take these actions
- Public health impacts and outcomes of these incidents

Papers and articles were investigated from worldwide sources without any year restrictions.

¹Evaluation of the Fate and Transport of Methanol in the Environment, 1999, Malcolm Pirnie, Inc., American Methanol Institute.

2. Methanol

2.1. Chemical properties

Under normal temperature and pressure conditions (20 °C and 1013 hPa), methanol is a clear, colourless and volatile liquid. It is miscible with water and with most organic solvents (alcohols, ethers, ketones, etc.). Due to its high vapor pressure (12.8 kPa), evaporation and volatilization processes should also occur alongside solubilization if accidentally released in seawater. Methanol is indeed classified as a dissolver that evaporates (DE) according to its physical and chemical properties (Table 1) and to the Standard European Behaviour classification². Once spilt, one part will dissolve in water, while the other will evaporate. In addition, the mixing of methanol with water is an exothermic process that results in heat release and volume contraction. Once concentrations have been diluted below toxic levels, the dominant mechanism of methanol loss is expected to be biodegradation.

Table 1. Chemical and physical properties of Methanol.

Chemical Formula	CH ₃ OH
CAS Number	67-56-1
UN Number	1230
Pictograms	
Common Name	Methanol, Methyl Alcohol, Wood Alcohol
Molecular Weight	32.04 g/mol
Appearance	Colourless, flammable liquid
Odour	Pungent, slightly sweet
Boiling Point	64.7°C (148.5 °F)
Melting Point	-97.6°C (-143.7 °F)
Solubility	Miscible in water
Density	0.792 g/cm ³ (at 20 °C)
Vapour Density	1.1
Theoretical behaviour (SEBC):	DE
Flash Point	11-12°C (53.6-53.8 °F)
Vapor Pressure	12.8 kPa (at 20 °C)

²Bonn Agreement, B. (1994). European classification system. Bonn Agreement: Counter-Pollution Manual.

Biodegradation half-lives	1 day in sandy silt loam 3.2 days in sandy loam
Degradation half-life in the atmosphere	17 days
Hydrolysis	Not hydrolysable
Aqueous photolysis	Not photolysable
K_{oc}	2.75, high mobility in soils
Log K_{ow}	-0.77
Ecotoxicity	LC ₅₀ : 15.32 g/L freshwater teleost <i>Oreochromis mossambicus</i> LC ₅₀ : 4.82 g/L cladoceran crustacea <i>Moina micrura</i>

*Data were extracted from: National Centre for Biotechnology Information (2025). PubChem Compound Summary for CID 887, Methanol. Retrieved January 16, 2025 from <https://pubchem.ncbi.nlm.nih.gov/compound/Methanol>.

2.2. Health hazards

Methanol is flammable and burns with a smokeless, clear blue flame which is difficult to see by daylight. Vapor density of methanol is 1.1 relative to that of air, i.e., near neutral in buoyancy. Consequently, the methanol vapours will respond more readily to dilution and dissipation caused by natural convection currents and forced ventilation³. Methanol vapours present a flammability risk when reaching a volume as low as 6 % in air, with a lower explosive limit (LEL) of 60,000 ppm⁴, particularly if the surrounding temperature exceeds the flash point (12 °C). Flash point refers to the minimum temperature at which a vapour can ignite when exposed to an external heat source, like a spark or flame, and in the presence of air. It is an important property for a safe handling of the products. According to the United States Department of Transportation's Hazardous Materials Regulations (HMR), a liquid with a flash point at or under 60 °C (140 °F) is a Class 3 flammable liquid. The flash point of methanol being 12 °C, it is a highly flammable substance that requires special precautions during handling, transport, and storage to minimize the risk of ignition and fire. The minimum ignition energy for methanol vapour is 0.2 mJ, which is similar to gasoline (0.14 mJ). Hence, an ignition source with sufficient

³Methanol Institute, 2011, <https://www.methanol.org/>

⁴ [National Institute for Occupational Safety and Health \(NIOSH\)](https://www.cdc.gov/niosh/)

energy to ignite gasoline will also ignite methanol and vice versa. Flame speed of methanol is 0.3 m.s^{-1} , which is very close to that of gasoline³.

Methanol can be toxic to humans if swallowed, inhaled or absorbed through the skin. According to the Centre's for Disease Control and Prevention, methanol is highly flammable, explosive, and toxic to humans even in small amounts. Large-scale transport and storage of methanol pose significant risks to human life in the event of an explosion or fire. Symptoms of methanol poisoning may not appear until 72 hours after ingestion and can include blindness, vomiting, heart failure, and death.

3. Description of past accidents

Descriptions of past accidents involving methanol can be found in this part. Summaries focusing on the key points of each accident are also provided. In case of missing information, "NA" (Not Available) was used.

3.1. Kanawha River, 1960

On 23 August 1960, a barge containing 3,000 tons of methanol docked at the city of Belle on the Kanawha River, West Virginia. The barge had been seriously damaged in transit and was leaking but neither the Water Resources Division nor the receiver were informed. On August 26, a routine sample of the river showed an abnormally low dissolved oxygen value in Charleston, and fish and lobsters were observed to be in distress. This was the beginning of the largest fish kill reported in the United States that year. An estimated 5,000,000 fish were killed and an unknown number of crayfish were killed. The river was impacted over 30 km. The Nitro wastewater treatment plant, 38 km downstream, was alerted, but no effects were observed there. No information on a later environmental monitoring was found. Nevertheless, the Clean Water Act was adopted in 1972, which made any pollutant discharge into navigable waters illegal. The loss of methanol while the barge was docked in Belle and before the leak was observed was estimated to be over 38 tons.

Date: 23 August 1960

Location: Kanawha River, West Virginia, USA

Cause: barge damaged during transport

Methanol accidental release: unnoticed leak from a methanol barge

Health impact/casualties: massive fish kill

Response: NA

Sources:

Gillenwater, L. E. (1965). Stream Pollution by Chemical Spills From Common Carriers. *Journal (American Water Works Association)*, 57(2), 201–207.
<http://www.jstor.org/stable/41264028>

3.2. Westward, 1980

On 16 November 1980, a loss of 7.8 tons of methanol from the Westward vessel was reported. The incident happened after a storm event at Cape St. James, Canada. Methanol was spilled in Pacific Ocean, but no information about any responses was available.

Date: 16 November 1980

Location: Cape St. James, Canada

Cause: storm event

Methanol accidental release: loss of 7.8 tons of methanol from the vessel

Health impact/casualties: NA

Response: NA

Sources:

https://publications.gc.ca/collections/collection_2022/eccc/en40/En40-327-1994-eng.pdf

database NATES (National Analysis of Trends in Emergencies System)

3.3. Iver Heron, 1988

On 31 March 1988, in Vancouver, Canada, 10 tons of methanol were spilt on the dock of the Iver Heron vessel and the chemical arrived then on the harbour. It was reported that a valve was left open. No information was available on the casualties nor on the actions taken after the spill.

Date: 31 March 1988

Location: Vancouver, Canada

Cause: open valve

Methanol accidental release: leak of methanol on dock and harbour

Health impact/casualties: NA

Response: NA

Sources:

https://publications.gc.ca/collections/collection_2022/eccc/en40/En40-327-1994-eng.pdf

database NATES (National Analysis of Trends in Emergencies System)

3.4. Maasgusar, 1989

On 15 March 1989, an explosion happened on the ship Maasgusar in Japan, a hundred kilometres from the shore.

The ship was loaded with 9 inflammable products including methanol. The ignition of the mixture of methanol vapours and air was probably the cause of the first explosion. Nevertheless, the ignition source remains unknown. It was reported that 23 crew members died and that the burning ship drifted for several days before sinking.

Date: 15 March 1989

Location: Yokohoma, Japan

Cause: ignition of air/methanol vapour

Methanol accidental release: NA

Health impact/casualties: 23 crew members died

Response: NA

Sources:

Stage CEE/Cedre 18-22 mars 1991. Lutte contre la pollution marine accidentelle. Cours général intégré axé principalement sur les substances dangereuses. Rappel de quelques accidents mettant en cause des hydrocarbures et des substances dangereuses / [H. REFLOCH](#) (1991)

3.5. Wilmington, 1992

On 15 April 1992, at Wilmington, USA, an explosion and a fire occurred in a storage tank containing 340,000 litres of methanol. This was surely caused by the ignition of the vapours from the tank, but the source of ignition remains unknown. Some methanol spilt into nearby river and there was fear after the rupture of a stepped bank.

Date: 15 April 1992

Location: Wilmington, North Carolina, USA

Cause: fire after ignition of vapours

Methanol accidental release: spill in river after tank explosion

Health impact/casualties: none

Response: NA

Sources:

Wilmington; North Carolina, USA. Tank vapours

https://backend.orbit.dtu.dk/ws/portalfiles/portal/288416988/904_2022_.pdf p.10

3.6. Frankfurt am Main, 1993

On 22 February 1993, 5.5 tons of methanol as well as other chemicals (2 tons of ortho-nitroanisole, 0.2 t of sodium hydroxide and 0.1 t of orthochlorobenzene) were released into the atmosphere in aerosol form at the Hoechst AG chemical plant in Frankfurt am Main, Germany. The wind-driven aerosol drifted over the city of Frankfurt. The chemical plant, the banks of the Main River and the Frankfurt suburbs were polluted by chemical fallout forming a sticky yellow-brown deposit. It reached the population and many people suffered from respiratory difficulties and itching.

The chemicals were released through safety valves following the build-up of pressure in a reactor. The release happened due to a combination of errors. A first operator forgot to start the stirring of the heated reaction, but when a second one noticed the mistake and started it, it triggered a sudden reaction that caused the pressure and temperature to rise, leading to the valves opening.

Some difficulties were observed during the post-accident management: it took 4 to 5 days to the company to coordinate and organize effective clean-up responses. But once they started, the redevelopment measurements were completed quickly: Removal of contaminated earth, recultivation of the gardens, cutting bushes and trees, cutting off and renewing street-surfaces, cleaning up footpaths and roofs of the houses.

Date: 22 February 1993

Location: Frankfurt am Main, Germany

Cause: sudden reaction in a reactor after stirring was started, causing valves to open

Methanol accidental release: 5,5 tons of methanol as part of a gaseous mixture

Health impact/casualties: population and environment contaminated. Itching and breathing disturbances among the population

Response: elimination of vegetation, cleaning or renewing surfaces

Sources:

Heudorf U, Peters M. Der Störfall in der Fa. Hoechst AG vom 22.2.1993--1. Ausmass der Umweltbelastung und Sanierungsverlauf [The chemical accident of the Hoechst AG facility 22 February 1993--1. Extent of environmental pollution and clean-up]. Gesundheitswesen. 1994 Jun;56(6):347-52. German. PMID: 8061466.

N° 4303 - 22/02/1993 - ALLEMAGNE - 00 - FRANCFORT (FRANKFURT AM MAIN)

<https://www.aria.developpement-durable.gouv.fr/accident/4303/>

3.7. Map Ta Phut, 1995

In September 1995, an explosion occurred during the unloading of a methanol tanker from a ship in the port of Map Ta Phut, Thailand. A fire followed the explosion and two crew members were killed. No further information was available on the cause of the explosion, nor on the response from the authorities.

Date: September 1995

Location: Map Ta Phut, Thailand

Cause: NA

Methanol accidental release: no data available

Health impact/casualties: two crew members died

Response: NA

Sources:

Methanol chemical response guide, Cedre, September 2012 p. 30

3.8. MV Floreana, 1998

On 1 August 1998, the coast guards from Houston-Galveston were informed that the M/V FLOREANA vessel had taken on water while docked at Care Wharf on the Houston Ship Channel, Texas, USA. An incident command post was set up and an environmental risk assessment was carried out. The vessel was loaded with sodium hydroxide (3.7 tons), methanol (4.4 tons) and sulfuric acid (136 kg). There were also 24 tons of diesel fuel on board. The agencies of the National Disaster Operational Workgroup (USEPA, TNRCC and TGLO) attended the scene and surveys were carried out. A containment boom was placed around the vessel. It was reported that none of the hazardous materials were detected in the water during the day. Underwater sonar images revealed that the vessel and its containers remained against the dock. Then, the containers were removed thanks to a crane. After 2 days of load removal, the ship was salvaged.

Date: 1 August 1998

Location: Care Wharf on the Houston Ship Channel, Texas, USA

Cause: NA

Methanol accidental release: no detection of chemicals in water

Health impact/casualties: none

Response: surveys, floating boom, environmental risk assessment

Sources:

<https://incidentnews.noaa.gov/incident/7321>

3.9. Perla, 2004

In March 2004, an explosion occurred while the chemical tanker Perla was loading methanol in the port of Taranaki, New Zealand. There were no casualties. No information was available on the cause of the explosion nor on the response that was established.

Date: March 2004

Location: Taranaki, New Zealand

Cause: NA

Methanol accidental release: NA

Health impact/casualties: none

Response: NA

Sources:

Methanol chemical response guide, Cedre, September 2012 p. 30

3.10. Vincuña, 2004

On 15 November 2004, two explosions occurred in the Chilean ship *Vicuña* during a methanol unloading operation at the port of Paranaguá in Brazil, causing the ship's tank to rupture. The chemical tanker ship was loaded with 14,000 tons of methanol. An estimated 7,000 tons of methanol were released into the sea. The methanol, highly inflammable and volatile, burnt, evaporated or diluted in the seawater within the first hours or days after the accident, as no trace of the product was monitored during the breakup of the ship. However, a total of approximately 400 tons of bunker oil, diesel oil, and lubricating oil, from the ship's tank leaked. Coastal ecosystems of the Paranaguá bay were contaminated by the oil spill, and fishing as well as shellfish capture were banned for about 60 days. The wreck of the *Vicuña* was surrounded by anti-pollution barricades 12 hours after the accident to prevent the pollution from spreading. Due to an insufficient number of workers, the delay into deploying the barricades caused the oil to stretch for more than 20 kilometres, covering beaches and rocks of the bays with oil. Two *Vicuña* crew members were found dead and two others were reported missing. Several theories were established about the cause of the explosions. The most plausible one suggested that the explosion came from a methanol tank, with the ignition source coming from the functioning of the cargo pump.

Date: 15 November 2004

Location: Paranaguá, Brazil

Cause: damaged discharging pump caused ignition from inside the methanol tank

Methanol accidental release: mostly burnt by fire from explosions and evaporated, rapid dilution in the seawater

Health impact/casualties: two crew members died, two others were reported missing

Response: no specific response towards methanol, but delayed anti-pollution barrages establishment against oil spill. Ban on fishing

Sources:

<https://www.ciimar.up.pt/hns/incident-detail.php?id=116>

<https://wwz.cedre.fr/Ressources/Accidentologie/Accidents/Vicuna>

Onório Figueira, Priscila. "Memories from the Disaster in 2004 of the Ship *Vicuña*." Environment & Society Portal, *Arcadia* (Spring 2021), no. 7. Rachel Carson Centre for Environment and Society. [doi:10.5282/rcc/9228](https://doi.org/10.5282/rcc/9228).

CHEMICAL TANKER "VICUÑA" EXPLOSION, FINAL INVESTIGATION REPORT, DIRECTORATE OF PORTS AND COASTS, Brazilian Navy, Directorate of Ports and Coasts

3.11. Metanol, 2005

On 30 April 2005, the chemical tanker Metanol docked at the French oil terminal of Lavéra, to begin unloading its 3,500 tons of methanol. Twenty minutes later, an explosion caused a fire on deck. The explosion occurred in the methanol tank number 12. It first produced a 20-meters-high flame and caused the rip-off of the tank lid. Flaming liquid methanol was sprayed onto the deck, causing a fire to break out. The fires on the deck and from inside the tank were quickly extinguished by the crew using fire extinguishers. No injuries were reported.

The Port State visited the ship on the same day to investigate the accident. Maintenance faults were first observed on the machine and the rescue equipment. An obvious lack of maintenance in the pump room was also reported. These deficiencies led to the vessel to be placed in an anchorage zone and immobilized by the French maritime authorities. On 13 May, the entire methanol load was transferred from the chemical tanker to the Sichem Marbella, a second tanker ship from the same company.

Four days later, inquisitors went on the Metanol ship to find out the possible cause and ignition source of the explosion. Their investigation revealed that the explosion was caused by the formation of an explosive air/methanol vapour atmosphere and a mechanical ignition source due to the malfunctioning of the cargo pump. The explosion occurred when the tank was more than 90% full, so the volume of gas was still relatively low, which limited the damage. If the explosion had occurred later in the unloading

Lessons learnt on past accidents involving Methanol

30/01/2025

process, it would certainly have been more violent, as the volume of vapours would have been much greater.

Date: 30 April 2005

Location: Lavéra, France

Cause: mechanical ignition of air/methanol atmosphere during methanol unloading

Methanol accidental release: mostly burnt by fire, no release into the sea reported

Health impact/casualties: none

Response: use of fire extinguishers against the fire, immobilization of the ship

Sources:

Technical survey report, BEAmer

https://www.bea-mer.developpement-durable.gouv.fr/IMG/pdf/RET_METANOL_Site.pdf

3.12. Slave Lake, 2006

During the night of the 17 January 2006, two trucks collided on the Highway 2, next to the city of Slave Lake, Canada. The collision happened due to snow on the highway. One of the trucks was a tanker truck loaded with 53 tons of methanol. Due to the accident, 45 tons of methanol were released into the environment. A river (Mitsue Creek) and a lake (Slave Lake) were contaminated. There were no details about a potential impact to the fauna. During the day, 80% of the methanol was contained and recovered but no information about the methods used was available.

Date: 17 January 2006

Location: Slave Lake, Alberta, Canada

Cause: truck accident due to weather conditions

Methanol accidental release: 45 tons of methanol released, contamination of river and lake

Health impact/casualties: NA

Response: containment and recovery of the methanol

Sources:

Inventaire déversements (Cedre in-house database)

3.13. Safmarine Leman, 2006

On 12 December 2006, 25 tons of methanol spilled into the hold of the tanker ship Safmarine Leman, offshore from the port of Viana do Costelo, Portugal.

It was caused by the rupture of a methanol container in the ship's hold, probably due to bad weather. As the ship had no cracks, the methanol remained contained within the vessel. The product was properly isolated by the crew and was transhipped into tanks later today at the port of Viana do Costelo. Clean-up operations were carried out by the shipowner in liaison with the Portuguese authorities and fire department, and required the use of 5 tons of carbon dioxide to minimize the risk of fire.

Date: 12 December 2006

Location: Viana do Costelo, Portugal

Cause: rupture of methanol container due to weather conditions

Methanol accidental release: none

Health impact/casualties: none

Response: isolation of the methanol in the hold, transfer to tanks, clean-up operations with carbon dioxide

Sources:

<https://www.aria.developpement-durable.gouv.fr/accident/32552/>

3.14. Barrel lost at sea, 2007

On 21 December 2007, a barrel containing around 20 litres of methanol was blown off a platform by high winds. It was also noted that the barrel was also not secured on the platform of the ship. The incident happened in Louisiana off of the Mississippi Delta. The United States coast guard (USCG) requested a drift study from the National Oceanic and Atmospheric Administration (NOAA) to enhance the formulation of their notice to Mariners and to assess if the barrel would wash ashore, giving an opportunity to recover the lost material.

Date: 21 December 2007

Location: Mississippi Delta

Cause: not secured barrel blown off by high winds

Methanol accidental release: lost barrel at sea

Health impact/casualties: none

Response: drift survey of NOAA to potentially recover the barrel

Sources:

<https://incidentnews.noaa.gov/incident/7737>

3.15. Clamecy, 2010

At a chemical plant in Clamecy, France, a leak of methanol from a tank supplying a chemical process (esterification) was observed by an operator who was making rounds during the restart of the process. The upper part of the tank collapsed and methanol spilled into the retention basin of the adjacent tank through a tear, as well as through a nitrogen injection hose in the tank.

The emergency response plan was activated: in-house firefighters doused the leak with water and covered the adjacent retention basin with foam to prevent any risk of ignition. The factory's rainwater network was isolated as a precaution. The leak stopped after a few minutes, when the tank level fell below the height of the tear. Around 10 tons of methanol were collected in the retention basin. The water/methanol mixture was then pumped out by a specialist company.

On the day of the accident, a combination of operator errors, including valve mismanagement and lack of checklist verification, led to depressurization of the tank, resulting in a leak caused by a tear in the tank wall.

Date: 28 September 2010

Location: Clamecy, France

Cause: operator errors

Methanol accidental release: no release in the environment

Health impact/casualties: none

Response: leak sprayed with water, retention basin containing methanol covered by foam, isolation of rainwater network

Sources:

<https://www.aria.developpement-durable.gouv.fr/accident/41340/>

3.16. Bunga Alpina, 2012

On 26 July 2012, the chemical tanker Bunga Alpina, docked in the Malaysian port of Labuan, caught fire while loading 6 tons of methanol. This was followed by a series of 3 violent explosions on board, resulting in the death of five crew members. The fire was said to have raged for 18 hours on board the vessel, while offshore supply vessels sprayed the fires with their water cannons. It was reported that a methanol tanker was ripped through by the explosion, but no further details were available about a potential spill.

Lessons learnt on past accidents involving Methanol

30/01/2025

It is believed that the explosions were caused by lightning strikes, due to a storm occurring during the loading procedures. According to local news reports, Labuan police confirmed that witnesses had reported seeing flashes of lightning during the fire.

Anti-pollution booms were quickly deployed around the vessel to contain the oil spill resulting from the breakout of the ship. Dispersant spraying tests were carried out. These proved ineffective due to the viscosity of the pollutant (heavy fuel oil). A slick drifted into Victoria Bay and reached the shoreline.

Date: 26 July 2012

Location: Labuan, Malaysia

Cause: lightning strikes causing explosions during methanol loading

Methanol accidental release: NA

Health impact/casualties: five crew members died

Response: no specific response towards methanol, but anti-pollution barrages and (ineffective) dispersants sprays against heavy fuel oil spill

Sources:

<https://gcaptain.com/tanker-explodes-malaysia-fire/>

<https://wwz.cedre.fr/Ressources/Accidentologie/Accidents/Bunga-Alpinia>

3.17. Rotterdam, 2016

On 19 July 2016, a methanol tank exploded at the Caldic Chemie Europoort chemical plant located in the Port of Rotterdam, Netherlands. The explosion happened during a methanol delivery operation by ship in the port. The incident caused no injuries and the situation was brought under control. No further information was available.

Date: 19 July 2016

Location: Rotterdam, Netherlands

Cause: NA

Methanol accidental release: none

Health impact/casualties: none

Response: NA

Sources:

<https://www.usinenouvelle.com/article/explosion-d-un-reservoir-de-methanol-a-rotterdam.N1261892>

3.18. Tasman Sea, 2017

On 21 January 2017, 3,300 litres of methanol spilt into the Tasman Sea, New Zealand. The spill came from a from Shell Todd Oil Services' Maui A platform, due to incorrect valve handling during a routine operation. The Environmental Protection Authority (EPA), Maritime NZ and WorkSafe New Zealand were immediately informed. The local coast guard Maritime NZ reported that the spill quickly became non-toxic and dispersed naturally by tidal currents and wave action. No actions were then established.

Date: 21 January 2017

Location: Tasman Sea, New Zealand

Cause: wrong valve handling during a routine operation

Methanol accidental release: 3,300 litres of methanol spilt into the Ocean

Health impact/casualties: NA

Response: none

Sources:

<https://www.stuff.co.nz/environment/89762171/methanol-spill-at-maui-a-platform-not-toxic>

3.19. Loss of storage containers, 2017

On 21 June 2017, the USCG Sector New Orleans contacted the NOAA regarding six missing chemical storage containers from a platform located in Black Bay. The containers contained a total of 200 litres of methanol. The disappearance of the containers was due to inclement weather. USCG requested information on the potential hazards of the chemicals, but no further details were reported.

Date: 21 June 2017

Location: Black Bay, Louisiana

Cause: inclement weather

Methanol accidental release: loss of containers

Health impact/casualties: none

Response: NA

Sources:

<https://incidentnews.noaa.gov/incident/9516>

3.20. Ohio River, 2018

On 3 January 2018, near Smithland, Kentucky, on the Ohio River, an incident involved two barges carrying 9,000 barrels of methanol and one barge carrying 9,000 barrels of styrene. The barges stranded and no spills were reported. The USCG Marine Safety Unit contacted the NOAA for information on the chemical properties of the substances involved but no further details were reported.

Date: 3 January 2018

Location: on the Ohio River, Smithland, Kentucky, USA

Cause: NA

Methanol accidental release: no spill reported

Health impact/casualties: none

Response: NA

Sources:

<https://incidentnews.noaa.gov/incident/9640>

3.21. National Automotive Chemical, 2021

On 18 February 2021, around 1 ton of methanol leaked from a tank truck at National Automotive Chemical in Cambridge. A significant amount of methanol leaked from the bottom of the tank onto Highland Avenue and then along the street. A portion of the avenue was then closed by the firefighters for several hours. The traffic was stopped and booms were deployed to protect the storm drains in the area. The Cambridge Street Department also provided two loads of sand to use with the booms to dam the liquid. Handlines for vapour suppression were also deployed to prevent the methanol vapor to ignite. However, it was not known how much methanol leaked into the nearby storm drains before emergency responders arrived. The Cambridge Water Department was notified about the leaking methanol. No injuries were reported.

Date: 18 February 2021

Location: National Automotive Chemical, Cambridge, Ohio, USA

Cause: NA

Methanol accidental release: tank leak

Health impact/casualties: none

Response: booms, loads of sand, hand lines for vapour suppression were deployed

Sources:

Emergency crews contained methanol leak from truck at Automotive Chemical, The Daily Jeffersonian (n.d.). <https://www.daily-jeff.com/story/news/local/2021/02/18/cambridge-300-gallons-methanol-leak-national-automotive-chemical/6797683002/> (accessed November 4, 2024).

3.22. Ohio river, 2023

On 28 March 2023, a barge loaded with 1,400 tons of methanol was among those to have crashed on the Ohio River near Louisville, Kentucky. This happened after that 10 out of 11 barges separated from a tugboat that collided with a "stationary structure" at the entrance to the Portland Canal, according to The Louisville Metropolitan Emergency Services (LMES). Seven of the barges contained loads of corn, while two contained soybean oil residues, and one contained methanol. The barge loaded with methanol was among the ones pinned against the McAlpine Locks and Dam (Figure 1) and partially submerged in the river.



Figure 1. Submerged barges pinned against the McAlpine Locks and Dam on the Ohio River near Louisville, Kentucky (Image: Via the Kentucky Energy and Environment Cabinet Twitter account).

Due to the immediate risk to public safety associated with the flammability and toxicity of methanol, air and water monitoring began, and the river was closed. A unified command including local, state, and federal agencies was established. The LMES reported that the city's Emergency Management Agency was leading the response effort, and personnel from the Kentucky Energy and Environment Cabinet monitored water and air quality around the site. The vessel's operator also activated the vessel

Lessons learnt on past accidents involving Methanol

30/01/2025

response plan. Vessel surveys were conducted, lightering and salvage plans were developed. The methanol barge was lightered while it was still pinned against the dam, and all other damaged barges were salvaged from the waterway. One week later, methanol was pumped from the pinned barge into a nearby receiver tank barge while monitoring for signs of spills of the chemical to the environment. After half a day of pumping, the salvage crew determined that enough methanol had been transferred to safely pull the stranded tank barge off the McAlpine Dam structure. The barge was then successfully removed from the river, and work continued to transfer the remaining methanol into the receiver barge. There was no indication of any methanol spills into the environment during the entire operation, and all air and water test results showed no detectable methanol. In total, more than 2,700 air quality samples have been taken since the incident occurred until the removal of the barge. Several municipal water companies that use the Ohio River as a source mentioned that they had increased their quality testing and filtration processes as a precautionary measure.

Date: 28 March 2023

Location: Ohio River, Kentucky, USA

Cause: boat collision with stationary structure

Methanol accidental release: barge with methanol partially submersed in the river, no release reported

Health impact/casualties: none

Response: river closure, pumping of methanol into a receiver tank, removal of barge, monitoring of air and water

Sources:

Another Disaster Hits Ohio River as Barge With 1,400 Tons of Methanol Submerges After Dam Incident, Vision Times (2023).

<https://www.visiontimes.com/2023/03/29/ohio-river-barge-methanol-spill.html>

Update: Methanol barge successfully removed from McAlpine Dam, April 07, 2023

<https://louisvilleky.gov/news/update-methanol-barge-successfully-removed-mcalpine-dam>

4. Conclusion and recommendations

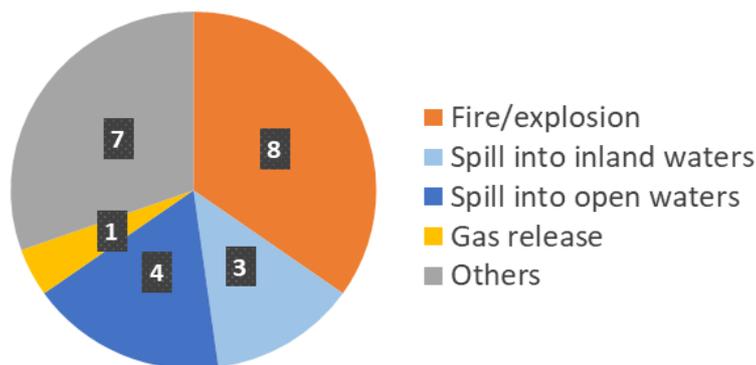
The accidents reported in this review happened over a broad period of time, between 1960 and 2023. They were located worldwide, as reported on Figure 2. It should be noted that the numbers of reported accidents also correlates with the reporting actions practices of each country.



Figure 2. Location of accidents involving methanol between 1960 and 2023, based only on incidents for which data are available. This is not an exhaustive list of all such accidents.

Out of the 22 accidents reported in this work, most of them were caused by fires or explosion. A few spills into the open sea were reported. Some accidents concerning methanol occurred at chemical plant storage tanks or due to leaks from tanks or trucks. Nevertheless, lessons learnt from accidents happening on land can benefit the decisions making processes for maritime transport. The different types of accidents are summarised on Figure 3.

a) distribution of accident types



b) accidents over time

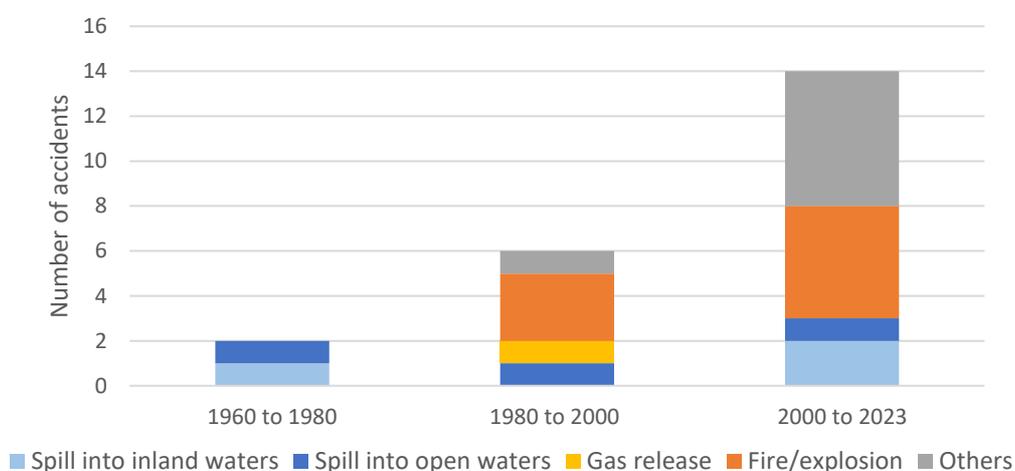


Figure 3. a) distribution of the accident types described in this review. “Others” refers to accidents where no methanol spills were reported and that mostly happened on land.
b) accident types per 20 years. No conclusion can be drawn regarding an increasing trend in accidents, as the rise in incidents may be attributed to improved reporting.

It can be seen that only a few methanol spills were reported before 1980, and more diverse accidents were reported after that year. This is linked with the application of several treaties⁵, like for instance the International Convention for the Safety of Life at Sea (SOLAS), 1974, effective in 1980, the MARPOL convention, effective in 1983, or later the United Nations Convention on the Law of the Sea (UNCLOS), effective in 1994. These treaties aimed, among others, at enhancing surveys and reports on maritime accidents.

The causes of the accidents were also investigated (Figure 4). It appears that 11 causes (out of 22) remain unknown. Among the accidents reported from 2000 to 2023, it can be seen that the causes are more diverse, which can also be due to an improved reporting.

⁵ <https://www.imo.org/en/OurWork/IIS/Pages/Reporting.aspx>

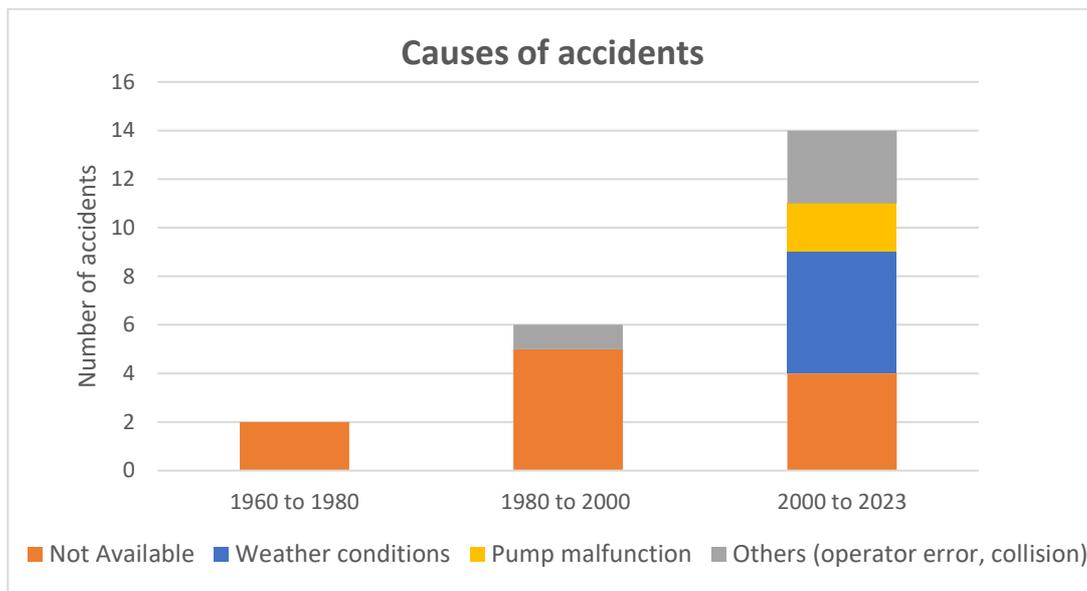


Figure 4. Causes of accidents per 20 years. Weather conditions were only reported as a factor after the 2000s. Half of the accidents causes remain unknown.

About the accident consequences, only the accidents involving fires or explosions were proven deadly. The different accident consequences per period of 20 years are reported on Figure 5.

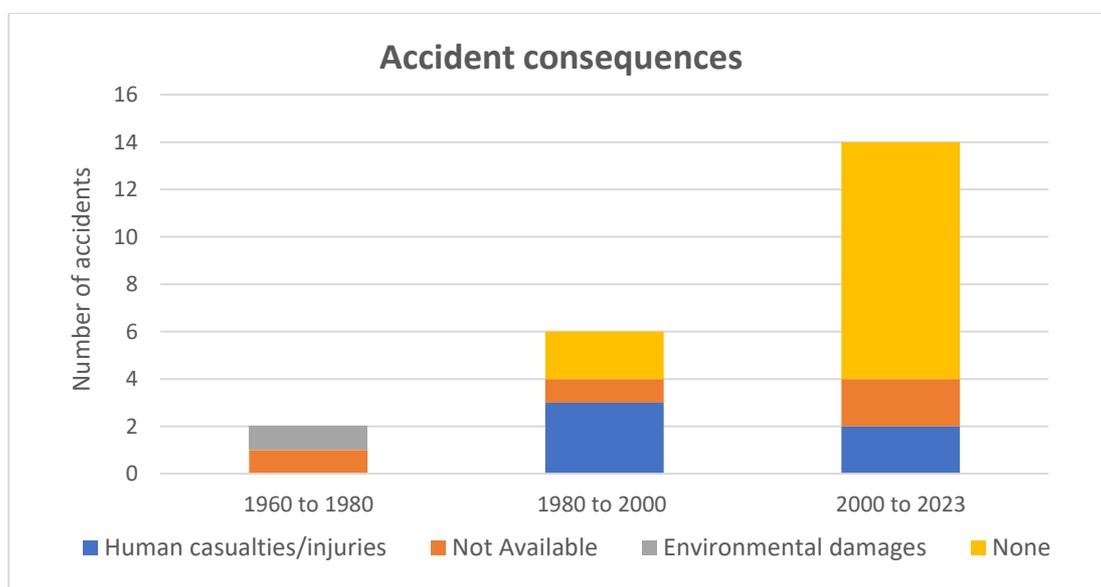


Figure 5. Consequences of accidents per 20 years. The number of accidents causing no casualties nor environmental damages seems to increase over time, but this trend also correlates with improved accident reporting activities.

All deadly methanol accidents involved fire or explosion events. The death toll is reported on Figure 6.

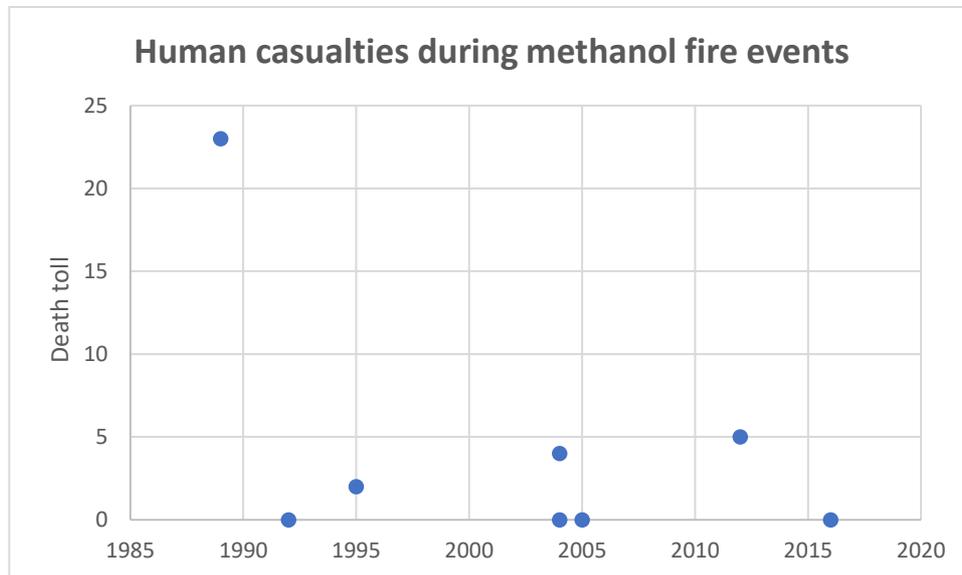


Figure 6. Death toll of methanol accidents involving fire or explosion over the years.

The deadliest accident happened in 1989 with the death of 23 crew members. In 2004, a malfunctioning pump led to the death of 4 people, while a fire caused by lightning strikes in 2012 caused the death of 5 people. There is no real declining trend in the number of deaths over the years.

Different actions were taken according to the type of accident. The responses were classified as satisfying, inefficient/delayed or not available when the information was not found (see Figure 7).

- **Fire prevention efforts:** Actions focused on preventing the spread of fires during the crisis.
- **Post-accident monitoring:** Monitoring was conducted to detect traces of methanol in the atmosphere and aquatic systems.
- **Environmental protection measures:** Anti-pollution booms were deployed after an oil spill caused by a methanol explosion, and fishing bans were established.
- **No response after spill into open sea:** Methanol was assumed to dissolve rapidly in the sea without causing harm, with no further response taken.

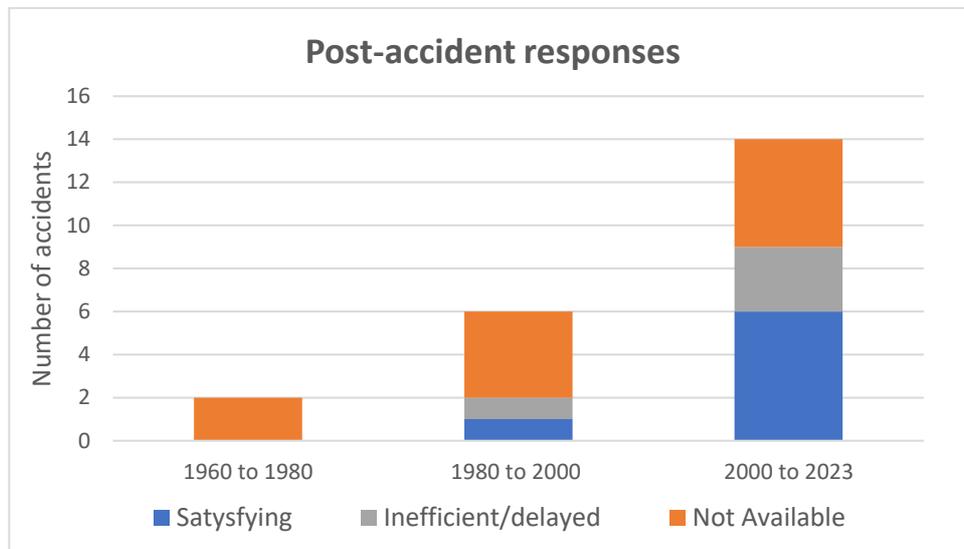


Figure 7. Types of post-accident responses described by this review.

Inefficient/delayed responses account for the ones that i) use unsuitable dispersants ii) took too long to establish. Increased reporting over the years can be seen, but a lack of knowledge sharing or investigation persists.

These results point out the lack of detailed information on the post-accident responses. The satisfying responses account only for less than a third of the total (7 out of 22).

With regard to the results of this review, different points can be highlighted:

- **Most of methanol accidents involved fires/explosions:** Deadly fires happened from diverse ignition sources: mechanical ones, lightning strikes, handling operations.

What is needed:

- Intensifications of inspections of the loading/discharging pumps
- Reduction of pumping frequency for older ships
- Emphasize the use of materials approved by Classification Societies on important equipment and restrict the use of reconditioned material

- **Persisting lack of investigation and knowledge sharing:** The precise causes of half of the total accidents remain unknown, especially the ignition sources of the fires. The responses given to some accidents are also missing, even though an improvement can be noted over the past 20 years.

What is needed:

- Detailed post-accident surveys, investigation of ignition sources

- Detailed documentation and knowledge sharing about the course of events

- **The establishment of effective responses was delayed:** Environmental contamination happened due to delay of response establishment, and some responses were ineffective because not suitable.

What is needed:

- Elaboration of a Contingency Plan, applicable to each locality/port, in order to minimize the environmental impacts
- Training in establishing cooperative action from various stages to produce effective monitoring and protective actions
- Enhancing knowledge access about chemicals behaviours to design suitable responses

Furthermore, in order to better prepare the responses or avoid any tragic accidents, the following aspects regarding methanol handling are recommended⁶:

Key safety measures:

- Ensure proper ventilation and avoid the formation of vapours, fumes, or aerosols.
- Wear self-breathing equipment if an exposure risk is present.
- Use appropriate protective clothing and footwear that prevent electrostatic discharge.
- Employ spark-proof and explosion-proof equipment.

Storage Guidelines:

- Use alcohol-resistant containers and equipment.
- Avoid heat sources, ignition points, oxidizing agents, acids, and bases.
- Tanks should be grounded, vented, and equipped with vapour emission control devices.
- Store in a dry, well-ventilated area, away from sunlight and radiation.

⁶Total petrochemicals 2010, INRS 2009



From Gases and Evaporators risk assessment towards an Integrated management of sea and land pollution incidents

MANIFESTS is a project co-funded by the European Union Civil Protection - DG-ECHO, developed in cooperation with RBINS, CETMAR, IMT Mines Alés, INTECMAR, IST, the UK Security Agency as associated partner and coordinated by Cedre.

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Lessons learnt on past accidents involving Liquefied Natural Gas (LNG)

30/01/2025

Work Package CROSS-BORDER/LAND-SEA PREPAREDNESS
AND RESPONSE TO INCIDENTS INVOLVING
AMMONIA / LNG / LITHIUM ION BATTERIES

Task PAST INCIDENTS REVIEW

Date 03/03/2025

Version 1

Author/s Laurent APRIN (IMT Mines Alès)

Partners



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Table of contents

1.	Background	5
1.1.	Context and MANIFESTS-Genius project objective	5
2.	Chemical properties of LNG	7
2.1.	Introduction	7
2.1.1.	Chemical composition of LNG	7
2.1.2.	General information on LNG.....	7
2.2.	Hazard associated to LNG	8
2.2.1.	Hazard linked to LNG storage temperature	8
2.2.2.	Hazard linked to associated with the flammability of LNG	8
2.2.3.	Hazard linked to the explosion of an air-gas mixture (vapour cloud explosion)	9
2.2.1.	Hazard linked to the sudden vaporization of LNG released on water	9
3.	Review of LNG accidents	9
3.1.	Accidents in industrial LNG facilities	10
3.2.	Accidents on LNG/LPG carrier and LNG/LPG Terminal	12
3.3.	Accidents on submarine LNG pipeline	19
3.1.	Synthesis of accidental review	21
3.2.	Conclusion.....	24
4.	References	26
4.1.	Documents	26
4.2.	Websites.....	27



LNG INCIDENTS REVIEW

06/03/2025

Tables of illustrations

Figure 1: Picture of the LNG ship Energy Progress with spherical tanks of a total volume of 147,558 m3.....	6
Figure 2: Analysis of the number of LNG-related accidents involving industrial sites, maritime transportation and transportation via submarine pipelines	21
Figure 3: Evolution of the number of accidents involving LNG or LPG until 1944.	22
Figure 4: Distribution of causes of accidents involving LNG for a) Industrial sites, b) LNG and LPG carrier and Terminal c) LNG and Submarine Pipeline	24
Table 1: LNG identification.....	7
Table 2: Methane and LNG physicochemical properties [1],[8], [15].....	8



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LNG INCIDENTS REVIEW

06/03/2025

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1. Background

1.1. Context and MANIFESTS-Genius project objective

Based upon the success of MANIFESTS, the MANIFESTS-Genius (from **G**ases and **E**vaporators risk assessment towards an **I**ntegrated management of sea and land **p**ollution incidents) project aims to strengthen preparedness and response capabilities for integrated management of coastal marine pollution by gases or evaporators, both at sea and on the shoreline. Specifically, WP3 aims to review past incidents in order to better known real incidents scenarios. This information will be used to build up hypothetical scenarios for desktop exercises where different aspects will be considered as information sharing among marine pollution authorities and response groups from different agencies/organisms with responsibilities during an incident near the shoreline to enhance efficient coordination of the land and sea response.

The present document aims to provide a literature survey of past accidents involving liquefied natural gas or, more generally, liquefied gases. The first part of this review is devoted to accidents on land, while the second focuses on accidents at sea or in port.

LNG (liquefied natural gas) refers to natural gas transformed into liquid phase. When LNG is at gaseous state when it is extracted and it is transformed to a liquid state by decreasing its temperature between -161°C and -163°C at ambient pressure. Liquefying LNG increases the volume carried while minimizing storage pressure (in its liquid state, liquefied natural gas (LNG) is 600 times less voluminous than in its gaseous state). This process makes it possible to reduce the thickness and weight of ships' tanks, and to transport it over long distances in LNG tankers. The largest ships in operation are 345 meters long, 54 meters wide and have a capacity of 266,000m³ of LNG. These ships need to be thermally insulated to keep the gas in a liquid state and avoid energy losses (Figure 1). When an LNG carrier reaches a receiving terminal, the LNG is unloaded and stored in large tanks until it is vaporized and fed into the natural gas distribution network. LNG is a hazardous liquid, as it is cryogenic and, as a natural gas, combustible.

Importantly, LNG is also increasingly used as a fuel for dedicated shipping vessels and cruise liners. As a result, these giants of the seas can sail the waters with considerably reduced emissions of polluting gases.



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LNG INCIDENTS REVIEW

06/03/2025



Figure 1: Picture of the LNG ship Energy Progress¹ with spherical tanks of a total volume of 147,558 m³

The other way of transporting LNG over long distances is via pipelines. Steel tubes with diameters ranging from 50 centimetres to one metre are welded together to form a pipeline, which can be over 3,000 kilometers long.

In this case, the gas is transported under pressure, as it takes up less volume and flows faster: it can reach speeds of up to 40 km/h in gas pipelines avec an operational pressure set at between 16 and 100 bar.

For safety and environmental reasons, gas pipelines are usually laid underground. However, in desert regions or where the ground is frozen (e.g. permafrost), pipelines are laid on the ground or, in the case of subsea pipelines, on the seabed.

In the current geopolitical and energy context, LNG transport is a strategic issue for the various European countries. The use of LNG ships operating clandestinely in the wake of the US embargo on gas exports from Russia, the sabotage of the Nordstream 2 pipeline in the Baltic Sea on September 26, 2022, and more recently the damage to the Balticconnector pipeline between Finland and Estonia by a ship's anchor on October 8, 2023, show that there is a high risk of accidents involving these modes of transport. In this context, the safety of these modes of transport requires particular attention to avoid major accidents.

¹ <https://www.lesechos.fr/2018/06/le-gaz-naturel-liquefie-en-plein-essor-pour-approvisionner-lasie-974764>



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2. Chemical properties of LNG

2.1. Introduction

In the context of the transportation of hazardous materials, LNG is identified with its CAS number and its UN number as follows:

Name	Identification number
CAS number	8006-14-2 (LNG) / 74-82-8 (Methane)
ONU Number	1972 (refrigerated fluid) / 1971 (pressurized fluid)

Table 1: LNG identification

The CAS number of a chemical substance, polymer, biological sequence and alloy is its unique registration number in the Chemical Abstracts Service (CAS) database, a division of the American Chemical Society (ACS).

ONU numbers are four-digit numbers that identify hazardous materials in the international transportation of these goods, such as explosive, radioactive, toxic, corrosive, flammable substances, etc.

2.1.1. Chemical composition of LNG

Under normal temperature and pressure conditions (i.e. at 25°C and 1.013 bar), LNG is in a gaseous state. LNG consists mainly of methane but also includes up to 10% of ethane and small amounts of other gases (propane and butane in particular).

The composition of LNG varies depending on the deposit from which it comes. The content of the various components respects the following values:

- Methane > 85 % (mol),
- Components C2 à C4 < 15 % (mol),
- sulfur < 0,01 % (masse)

LNG is an odourless, colourless, non-corrosive and non-toxic liquid. In its gaseous phase, LNG can have an anesthetic effect and/or an asphyxiant effect by reducing the oxygen content of the atmosphere. Contact with the product can cause cold burns.

2.1.2. General information on LNG

As LNG is a mixture that varies according to the gas field, it is tricky to provide a precise composition and universal physicochemical properties. However, orders of magnitude of the physicochemical properties of LNG can be provided by distinguishing three types of compositions (Table 2):



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06/03/2025

- Pure methane,
- « Light » LNG (methane 97 %),
- « Heavy » LNG (methane 88 %).

Name	Pure methane	“Light” LNG	“Heavy” LNG
Boiling point [°C] ^[1]	-162	-161	-160
Liquid density at boiling point [kg/m ³] ^[1]	423	431	464
Vapour density at boiling point [kg/m ³] ^[1]	1.81	1.80	1.76
Vapour density à 20°C [kg/m ³] ^[1]	0.67	0.69	0.78
Heat of combustion [MJ/kg] ^[1]	50	50	49
Flammability range [%] ^[1]	5-15	4.9-14.9	4.4-14.4
Flash point at atmospheric pressure [°C] ^[8]	600	-	-
Auto ignition temperature [°C] ^[8]	-188	-	-
Solubility in water [mg/L] ^[15]	22	-	-

Table 2: Methane and LNG physicochemical properties [1],[8], [15]

2.2. Hazard associated to LNG

2.2.1. Hazard linked to LNG storage temperature

As LNG is stored and transported at a temperature of around -160°C, contact between LNG and materials not specifically designed for such low temperatures (known as cryogenic temperatures) can cause them to become fragile and brittle. Furthermore, contact between LNG and the human body can cause cold burns.

2.2.2. Hazard linked to associated with the flammability of LNG

LNG is a flammable liquid, which means that, like petrol or diesel, the vapours it forms can combine with oxygen in the air under certain conditions and give rise to a combustion reaction. A combustion reaction can give rise to various potentially dangerous phenomena, depending on the exact conditions in which it takes place.

A distinction is thus made between:



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- A pool fire, caused by the ignition of LNG vapours created by a pool of LNG released on ground or water. This phenomenon lasts until the LNG is exhausted.
- A cloud fire, caused by the delayed ignition of a drifting cloud of LNG vapours. This phenomenon lasts only a few seconds, with the flame quickly flowing back towards the source of the leak as soon as the contents of the cloud are consumed.
- A “torch” fire, caused by the ignition of a continuous plume of LNG or pressurized natural gas. This phenomenon lasts as long as the leak is fed.

2.2.3. Hazard linked to the explosion of an air-gas mixture (vapour cloud explosion)

The ignition of an LNG vapor cloud or a natural gas plume can create blast waves. In open air, this excess pressure can potentially present a danger to the people, the environment and structures. Potentially dangerous pressure waves (detonation) can potentially appear in confined or congested environments (for example certain complex units in refineries or chemical plants).

2.2.1. Hazard linked to the sudden vaporization of LNG released on water

In the event of a major spill of LNG into the water, a rapid vaporization phenomenon (called “rapid phase transition” or “RPT”) can occur, causing overpressure known as a “cold explosion” [3]. This danger exists particularly at the landing stage.

3. Review of LNG accidents

A review of the past worldwide incidents has been conducted to further investigate the possible hazards from LNG release. All the events aim to summarise the findings on the incidents in LNG facilities, LNG ship transport and LNG transport by pipeline based on the review of the most exhaustive incidents/ accidents database.



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06/03/2025

The following description of accident is taken from different papers issued from:

- Base de données ARIA, titled “Accidentologie Gaz Naturel Liquéfié”, [4]
- Cabioc’h et al titled “Accidents on Vessels Transporting Liquid Gases and Responders Concerns: The Galerne Project”, in 2009, [5]
- CLP Power Hong Kong Limited, titled “Environmental Resources Management. Annex 5c_Review of Industry Incidents” in 2018, [6]
- Congressional Research Service, titled “Liquefied Natural Gas (LNG) Import Terminals: Siting, Safety, and Regulation”, [7]
- FEBIMA, titled “Report on the investigation into a serious injury on board LNG tanker SUMMIT LNG” in 2020, [10]
- GAS Dedicated to LNG and Royal Haskoning, titled “Projet de terminal methanier du Verdon, Etude préalable sur les dangers”, [11]
- Japan Transport Safety Board, titled “Marine Incident Investigation Report” in 2013, [12]
- Michot titled “LNG Safety and Security”, [13]
- Pitblado et al. titled “Consequences of LNG Marine Incidents” in 2004, [16]
- Sandia National Laboratories, titled “Guidance on risk analysis and safety implication of a large liquified natural gas (LNG) spill over water in 2004, [14]
- SIGTO (Society of International Gas Tankers Terminal and Operators Ltd.) titled “Safety Havens for Disabled Gas Tankers” in 2003, [17]
- U.S. Coast Guard titled “Major LNG incidents from the final environmental impact statement impact for the port Delfin LNG project deepwater port application”, in 2016, [18]
- Wang, D, titled “Risk analysis of fire/explosion to the LNG fuelled passenger ferries”, [19].

Web site [20], [21], [22],

- [23], [24], [25], [26], [27], [28], [29], [29], [30] and [31]

3.1. Accidents in industrial LNG facilities

1. *Cleveland, Ohio, USA (1944) - Mechanical failure*

“In the East Ohio Gas Company complex an LNG tank failure and no earthen dike. A vapor cloud formed and filled the surrounding streets and storm sewer system. Natural gas in the vaporizing LNG pool ignited. the explosion killed over 160 people, severely injured hundreds more and demolished an entire neighbourhood.”

2. *Canvey Island; Essex; UK (1965) – Human error*

“During LNG transfer, an error resulted in the release of LNG. The release became ignited, causing one person to be seriously burned.”

3. *Portland, Oregon, USA (1969) – Human error*



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06/03/2025

“An explosion occurred in an LNG tank under construction. No LNG had ever been introduced into the tank. The cause of the accident was the accidental removal of blinds from natural gas pipelines which were connected to the tank. This led to the flow of natural gas into the tank while it was being constructed.”

4. Montreal-East, Quebec, Canada (1972) – Human error

“A back flow of natural gas from the compressor to the nitrogen line occurred during defrosting operations at an LNG liquefaction and peak shaving plant in Montreal East. The valves on the nitrogen were not closed after completing the operation. This caused over pressurization of the compressor and the natural gas entered the control room (where operators were allowed to smoke) through the nitrogen header. An explosion occurred when an operator tried to light a cigarette.”

5. Staten Island, New York, USA (1973) – Human error

“In February 1973, a fire started while repairing the interior of an empty storage tank at Staten Island. The resulting increase in pressure inside the tank was so fast that the concrete dome on the tank lifted and then collapsed down inside the tank killing the 37 construction workers inside”

6. Das Island, United Arab Emirates (1978) – Mechanical failure

“An accident occurred due to the failure of a bottom pipe connection of an LNG tank. The tank had a double wall (a 9% nickel steel inner wall and a carbon steel outer wall). Vapor from the outer shell of the tank formed a large heavier-than-air cloud which did not ignite.”

7. Cove Point, Maryland, USA (1979) – Unknown

“An explosion occurred in an LNG tank under construction. No LNG had ever been introduced into the tank. The cause of the accident was the accidental removal of blinds from natural gas pipelines which were connected to the tank. This led to the flow of natural gas into the tank while it was being constructed.”

8. Bontang, Indonésie (1983) - Mechanical failure

“A rupture in an LNG plant occurred as a result of over pressurization of the heat exchanger caused by a closed valve on a blow down line. The exchanger was designed to operate at 25.5 psig. When the gas pressure reached 500 psig, the exchanger failed and the explosion occurred.”

9. Test Site Mercury, Nevada, USA (1987) – Unknown

“In August 1987 an accidental ignition of an LNG vapour cloud occurred at the U.S. Department of Energy Nevada Test Site during large scale tests involving spills of LNG. The cloud was accidentally ignited and damaged and propelled polyurethane pipe insulation outside the fence.”



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06/03/2025

10. Thurley, United Kingdom (1989) – Human error

“While cooling down vaporisers in preparation for sending out natural gas from LNG Peak shaving Facility, low-point drain valves were opened. One of these valves was not closed when pumps were started and LNG entered the vaporisers. LNG was released into the atmosphere and the resulting vapor cloud ignited, causing a flashfire that burned two operators.”

11. Skikda, Algeria (2004) – Unknown

“A steam boiler that was part of an LNG production plant exploded, triggering a second, more massive vapor-cloud explosion and fire. The explosions and fire destroyed a portion of the LNG plant and caused 27 deaths, 74 injuries, and material damage outside the plant’s boundaries.”

12. Nigeria (2005) – no information on causes

“A 28-inch LNG underground pipeline exploded in Nigeria and the resulting fire engulfed an estimated 27 square kilometres.”

3.2. Accidents on LNG/LPG carrier and LNG/LPG Terminal

1. Arzew, Algeria (1964) – external event

“While loading LNG, lightning strike to the forward vent riser of the Methane Progress ignited vapor which was being routinely vented through the venting system at the time.”

2. Arzew, Algeria (1965) - Unknown

“A similar occurrence also occurred in early 1965 when the Methane Progress shortly after leaving port. Both times, the flame was quickly extinguished by purging with nitrogen through a connection in the riser.”

3. Arzew, Algeria (1965) - Unknown

“The Jules Verne, a ship carrying 25,500m³ of LNG, had an LNG spill onto tank cover plates due to overfilling while loading at Arzew in May 1965. The spill was attributed to an inadequately trained cargo handling officer. The spill caused minor damage to the ship which delivered its cargo before repairs were affected”

4. Canvey Island; Essex; UK (1965) – Human error

“Early 1965 Methane Princess suffered a spill alongside at Canvey Island when the LNG discharging arms were disconnected prematurely before the lines had been completely drained, causing LNG liquid to pass through a partially opened valve and onto a stainless-steel drip pan placed underneath the arms. This caused a star-shaped fracture to appear in the deck plating in spite of the application of seawater.”



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06/03/2025

5. Negeshi, Japan (1970) – External event

“A few hours out of Japan heavy seas caused sloshing of cargo tanks in LNG ship steaming from Japan to Alaska. A thin membrane wall bent in four places and a half inch crack formed in a weld seam.”

6. Boston, Massachusetts, USA (1971) – Mechanical failure

“LNG ship “Descartes” had gas leak from tank, faulty connection between tank dome and membrane wall, crew reportedly tried to conceal leak from authorities.”

7. La Spezia, Italie (1971) – Rollover phenomena

“First documented LNG “rollover” incident, where two differing temperatures and densities of LNG mix. This accident, involving LNG ship Esso Brega and La Spezia LNG Import Terminal, was caused by a “rollover” during which two layers of LNG with different densities and heat contents were formed. The sudden mixing of these two layers causes a sudden increase in pressure damaging the tank roof and causing LNG vapor to discharge safely from the tank safety valves and vents. The release of large volumes of vapor was approximately 2,000 tons of LNG vapor.”

8. 1973, Malacca Straits (1973) - Collision

“The world Bridgestone, a 74,000 m³ fully refrigerated LPG carrier, loaded with butane and propane for Japan was in collision with an oil tanker in the Malacca Straits. The hold around No. 1 cargo tank flooded but with no immediate threat to the cargo containment. The ship was accepted into Singapore waters where temporary repairs were carried out.”

9. Tokyo Bay, Japan (1974) - Collision

“The Yuyo Maru LPG/oil products carrier with four fully refrigerated LPG centre tanks of about 47,500 m³ total capacity and with wing tanks of normal oil tanker construction capable of carrying 32,000 m³ of oil products. While loaded with a full cargo of butane and propane in the centre tanks and of naphtha in the wing tanks, she was in collision with a bulk carrier, Pacific Ares, in Tokyo Bay. Naphtha spilled from an opening of 24 metres in length and extending to below the water line in No. 1 Starboard Wing Tank. The naphtha immediately caught fire and flames enveloped the whole of the Pacific Ares and the starboard side of the Yuyo Maru. Twenty-nine of the crew of the bulk carrier and five men on the gas carrier were killed. LPG vapour escaping from the safety valves and ullage fittings of Nos. 1, 2 and 3 LPG tanks ignited and burnt continuously at the points of emission. The Yuyo Maru continued to burn and fire spread to Nos. 2 and 3 Starboard Wing Naphtha Tanks with sporadic eruptions of flame. Despite major efforts by firefighting tugs, it was not possible to extinguish the fires. Finally, after 19 days, the ship, still burning and having been towed far out to sea, was sunk by torpedo and gunfire. It is noteworthy that despite the considerable initial collision damage, the fierce and protracted burning of the naphtha cargo in and around the ship and the ignition of the gas escaping on deck from the LPG tanks, no rupture or explosion of the LPG cargo tanks



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06/03/2025

took place and there was no release of the liquefied gas cargo either into the hull or to the sea until the final bombardment and sinking. The 47,000 m³ of LPG in her refrigerated central tanks were surrounded by fire when the 32,000 m³ of naphtha cargo located in her lateral tanks took fire. The LPG escaped from the safety valves and burnt. Finally, after 20 days of burning the ship has been voluntarily sunk. Except from the safety valve, no gas went out the tanks."

10. Terneuzen; Algeria (1974) – Collision

"LNG ship "Euclides" sustained contact damage with another vessel, causing damage to bulwark plating and roller fairlead."

11. Canvey Island; Essex; UK (1974) – Collision

"The coaster "Tower Princess" struck the "Methane Progress" as it was tied up at the LNG jetty tearing a 3 ft gash in its stern. No LNG was spilled and no fire."

12. Massachusetts, USA (1974) – Mechanical failure

"40 gallons of LNG leaked during loading, as a result of a power failure and the resulting automatic closure of the safety valves. The leak resulted in several fractures to the deck plates."

13. Bontang, Indonesia (1977) - Mechanical failure

"During the filling of the Aquarius cargo tank, LNG overflowed through the vent mast serving that tank. The incident may have been caused by difficulties in the liquid level gauge system. The high-level alarm had been placed in the override mode to eliminate nuisance alarms."

14. Strait of Gibraltar (1979) - Grounding

"While loaded with 99,500 m³ of LNG, the ship El Paso Paul Kayser ran at speed onto rocks and grounded in the Straits of Gibraltar. She suffered heavy bottom damage over almost the whole length of the cargo spaces resulting in flooding of her starboard double bottom and wing ballast tanks. Despite this extensive damage, the inner bottom and the membrane cargo containment maintained their integrity. Five days after grounding, the ship was refloated on a rising tide by discharge of ballast by the ships' own pumps and by air pressurisation of the flooded ballast spaces."

15. Cove Point, Maryland, USA (1979) - Mechanical failure

"In October 1979, while discharging cargo Mostafa Ben Bouliad at Cove Point, Maryland, a check valve in the piping system of the vessel failed releasing a small quantity of LNG. LNG leaked through an inadequately tightened LNG pump electrical penetration seal, vaporized, passed through 200 feet of underground electrical conduit, and entered the substation. Since natural gas was never expected in this building, there were no gas detectors installed. The normal arcing contacts of a circuit breaker ignited the natural



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06/03/2025

gas-air mixture, resulting in an explosion. The explosion killed one operator in the building, seriously injured a second and caused about \$3 million in damages.”

16. Passage from Indonesia to Japan (1980) -Mechanical failure

“While on passage from Indonesia to Japan, the propeller tail shaft of the Libra LNG carrier fractured, leaving the ship without propulsion. The Philippine authorities granted a safe haven in Davao Gulf to which the ship was towed. Here, with the ship at anchor in sheltered water, the cargo was transferred in 32 hours of uneventful pumping to a sister ship moored alongside. The LNG Libra was then towed to Singapore, gas-freeing itself on the way and was repaired there. In this casualty, there was, of course, no damage to the ship's hull and no immediate risk to the cargo containment.”

17. Port of Tobata, Japan (1980) - Grounding

“Approaching Tobata Port, Japan to discharge, the Taurus LNG ship grounded in heavy weather with extensive bottom damage and flooding of some ballast tanks. After offloading some bunkers and air pressurising the ruptured ballast spaces, the ship was refloated four days grounding. Despite the extent of bottom damage, the inner hull remained intact and the spherical cargo containment was undistributed. After a diving inspection at a safe anchorage, the ship proceeded under its own power to the adjacent LNG reception terminal and discharged its cargo normally.”

18. Thyborøn Kanal, Denmark (1980) – grounding

“The pressurized stranded vessel Regitze Tholstrup (400 m³ of butane) grounded on the Thyborøn Kanal in Denmark. It was lightered from the coast.”

19. Fos sur Mer, France (1980) - Capsizing

“This ship capsized in bad weather off Fos sur Mer (Southern France). She was carrying 1000 tons of butane and was towed offshore and sunk by Navy divers.”

20. Persian Gulf, passage from Ras Tanura to Fujairah (1984) – External events

"This vessel Gaz Fontaine of 40,232m³ *as built in 1969 and can be considered to be one of the first generation of fully refrigerated LPG carriers. She had loaded 18,440 tons of propane and butane in three prismatic tanks. She was on passage from Ras Tanura to Fujairah when she was attacked by Iranian aircraft with air to ground missiles, three of which hit the vessel, causing severe damage. A hole 3 x2m was blown in the roof of No. 3 tank and much of the cargo pipework and electrical cabling on deck was severely damaged. As would be expected, a serious fire developed on deck and subsequently spread to the accommodation, but luckily not to the engine room. The crew abandoned ship and two days later, a salvage team arrived on the scene and extinguished the fires with powerful water jets and foam from a salvage tug. The vessel was then towed to a safe anchorage some 15 miles off Dubai and during this period work started on securing the vessel's gas-tight integrity. Services were supplied by barge until the vessel's engine room could be recommissioned and six weeks later, 17,204 tonnes of the original cargo



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LNG INCIDENTS REVIEW

06/03/2025

had been discharged by ship-to-ship transfer to the LPGC Ribagorca, using Gaz Fountain's own pumps. The vessel was then gas freed prior to repairs."

21. Isabella (1985) – Overfilling

"The Isabella of 35500 m³ cargo capacity had an LNG spill onto its deck due to a cargo tank overflow on 14 June 1985. The spill has been attributed to cargo valve failure during discharging of cargo. The spill caused severe cracking of steelwork"

22. Skikda, Algeria (1989) - Loading

"The Tellier of 40000 m³ capacity had an LNG spill onto its deck during loading at Skikda on 12 June 1989. The spill caused severe cracking to the deck. The spill resulted from the vessel breaking free from its moorings. More minor spillages are reported in reference."

23. Port of Brindisi, Italy (1990) -Fire

"The vessel, a 2,999 m³ semi-pressurized LPG carrier with cylindrical tanks was discharging propylene at Brindisi when a fire started between the compressor house and No. 3 tank. The vessel was towed out to sea with No. 3 tank dome burning. This continued to burn for a further 22 days after which explosive charges were laid to breach the domes of the four remaining tanks and allow the gas to burn off. This situation continued for a further 16 days until the vessel was scuttled."

24. East china Sea (1996) - Shipwreck

"Gas Luck carrier was carrying 1,500 tons of butane gas and sank in bad weather in the East China Sea".

25. Boston, Massachusetts, USA (1996) – External fire event

"Loaded LNG carrier sustained electrical fire in main engine room whilst tied up alongside terminal. Fire extinguished by crew using dry chemicals. Cargo discharged at reduced rate (over 90 h instead of 20 h) and vessel sailed under own power."

26. Port of Sakai Senboku, Japan (1997) - Collision

"LNG Capricorn tanker sustained damage to shell plating on contact with mooring dolphin at pier. No spillage or damage to cargo system."

27. Florida, USA (1997) - Grounding

"The Igloo Moon was carrying 6,600 tons of butadiene when she ran aground on rocks off Florida. No leak was noticed. After a few days, the cargo was off-loaded and the ship freed and towed up to a port after inspection."

28. Boston, Massachusetts, USA (1998) – Human factor

"LNG carrier was discharging cargo when arcs of electricity shorted out two of her generators. The US coast guard removed the vessel's certification of compliance as this incident was the latest in a series of deficiencies on the vessel."



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LNG INCIDENTS REVIEW

06/03/2025

29. Trinidad (1999) -Collision

“The LNG carrier GDF-SUEZ Point Fortin collided with a pier after it suffered an engine failure. There was no pollution or any injuries. The pier was closed for 2 weeks. \$330,000 of damage done.”

30. Everett, Massachusetts, USA (2001) – Mechanical failure

“Suspected over pressurisation of No. 4 cargo tank resulted in some cracking of the outer tank dome. A minor leakage resulted in offloading being temporarily suspended. The tank itself was not damaged and offloading was completed. Vessel not detained.”

31. Moss Rosenberg Design LNG Carrier (2001) - Overfilling

“A 125,000 Moss Rosenberg design LNG Carrier experienced an overfilling of a cargo tank, during cooldown operations, at a U.S. LNG Terminal. The spillage of LNG resulted in cracks appearing in one tank cover. The cargo containment system was not damaged nor was there any structural damage to the vessel.”

32. Chinese sea, Hong Kong (2002) - Fire

“This 75,000 m³ refrigerated LPG tanker was loaded with 10,000 m³ propane and 10,000 m³ butane. A fire broke out in the machine room (ship on anchor) and the fire extinguished after 3 days. Due to the lack of refrigeration, the pressure increased in the tanks but the off-loading operations were successful.”

33. East of the Strait of Gibraltar (2002) – Collision

“LNG carrier Norman Lady was struck off Gibraltar by the USS Oklahoma City, a Navy nuclear submarine. Minor damage to both vessels was caused by submarine periscope. Ship suffered a leakage of seawater into the double bottom dry tank area. The company said the vessel, had already unloaded its LNG cargo in Barcelona, Spain.”

34. Port Fortin, Trinidad, Caracas (2006) – Mechanical failure

“Atlantic LNG reported that an accident occurred at its Train 2 facility at Point Fortin, Trinidad when a temporary eight-inch isolation plug was blown by built-up pressure. The Train 2 facility had been shut down due to the detection of a gas release from a two-inch pipeline. The release of natural gas was brought under control, and personnel returned. While the company was carrying out repairs the plug blew injuring one worker. It had been filled with inert gas to facilitate repairs.”

35. Amman, Jordanian (2006) - Fire

“A tanker carrying liquefied natural gas caught fire as it unloaded in Aqaba, injuring 12 people, the manager of the Jordanian port said. Four of the injured were firefighters, who needed an hour to bring the blaze under control, said Awwad al-Maaytah, the director general of Aqaba Port Authority. The other injured were crewmen. The ship was promptly evacuated and towed away from the pier in the Red Sea port having unloaded only half of its cargo. Al-Maaytah said the cause of the fire was under investigation. “



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LNG INCIDENTS REVIEW

06/03/2025

36. Off Cape Cod, USA (2008) – Mechanical problem

“Coast Guard and tugboat crews rescued a liquefied natural gas tanker named Catalunya Spirit. The ship was carrying a full load of LNG from Trinidad and Tobago to Boston when it became disabled. Just 5-years-old, the fully laden LNG carrier was corralled by four tugboats about 25 miles east of Provincetown. Apparently, about 3 a.m. Monday its propulsion system shut down because of a computer malfunction according to the Coast Guard. The 933-foot Spanish-flagged LNG tanker Catalunya Spirit was heading from Trinidad to the LNG facility in Everett. After several days of troubleshooting, repair specialists determined a malfunctioning boiler feed pump, which supplies water to the main propulsion boilers, caused the Catalunya Spirit's loss of power and propulsion. Captain of the Port of Boston reviewed and approved the final repair certification presented by Lloyd's Register and Teekay Corporation. The LNG delivery through Boston Harbor was cancelled. “

37. South Hook LNG Terminal (2009) – Human error

“A maximum of ten litres of LNG was spilled and “immediately vaporized”, because of the unintended activation of the emergency shutdown system, which caused powered emergency release couplings to separate, discharging LNG.”

38. Montoir de Bretagne terminal, France (2010) – Unloading problem

“The incident occurred when liquid passed into the gas take-off line during discharge operations. The damage sustained extended to part of the ship's manifold and its feed lines.”

39. Withnell Bay facility, Australia (2010) – Loading problem

“The ship suffered cryogenic burns when 2,000 to 4,000 litres of LNG were spilt.”

40. Yung An LNG Terminal, Taiwan (2011) – Unloading problem

“The vessel's master decided to suspend the discharge and move the ship off the berth but the problems were eventually rectified and the vessel returned to complete the discharge of its cargo.”

41. Pyeongtaek LNG terminal, South Korea (2011) - Unloading problem

“The ship disconnected from the berth after what was described as a very small leak of LNG was reported around the top of one emergency release coupler shortly after a scheduled overhaul of the unloading arms had been completed. Seals and ball valves were replaced on the unloading arms and discharge recommenced using the remaining two arms. “

42. Off Zeebrugge, Belgium (2015) – Collision

“On 6th October 2015, the LNG carrier Al Oraiq collided with the cargo vessel Flinterstar off Zeebrugge (Belgium) in a very busy shipping area, at the crossroads of the North Sea traffic separation schemes and the access channels to the ports of Zeebrugge and



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LNG INCIDENTS REVIEW

06/03/2025

Antwerp. While the LNG carrier was able to enter the port of Zeebrugge for inspection, the damaged bulk carrier grounded and sank on a shallow sand bank 5.3 nautical miles from the coast. It was carrying 3,000 tonnes of steel and contained around 430 tonnes of heavy fuel oil (IFO 380) and 115 tonnes of diesel in its bunker tanks. “

43. Barcelona LNG terminal, Spain (2015) – Mechanical problem

“The LNG carrier Fuwairit, owned by the Japanese shipping company Mitsui OSK Lines, leaked LNG vapors in the port of Barcelona in 2015. At Navantia-Ferrol, four cracks in the ship's deck had to be repaired after the simultaneous failure of a valve and a high-level alarm. At the top of tank no. 1, a pool of floating LNG formed and, on contact with the salt water, vaporized, creating a gas cloud visible through the condensation of the seawater vapor. “

44. Strait of Gibraltar (2022) – Collision

“Accident collision and subsequent loss of the geared bulk carrier OS35, a 20,947GT vessel registered in Tuvalu. The accident occurred on 29th August 2022 as the OS35 was departing the Bay of Gibraltar anchorage and collided with the LNG carrier Adam LNG. The impact caused a breach in holds two and three of the OS35, leading to the vessel's-controlled beaching to the East of Gibraltar, where it was subsequently dismantled.

The investigation was conducted in accordance with the Gibraltar Merchant Shipping (Accident Reporting and Investigation) Regulations 2012. Its primary objective was to enhance maritime safety and prevent future incidents of a similar nature. “

3.3. Accidents on submarine LNG pipeline

1. Ghislenghien, Belgium (2004) - Human error

“A gas pipeline carrying natural gas from the Belgian port of Zeebrugge to northern France explodes, killing 23 people. The cause of the incident is still under investigation, but it appears that a contractor accidentally damaged the pipeline. “

2. t. Mary Parish, Louisiana (2006) – Dropped object

“A ruptured high-pressure natural gas pipeline was struck by a 5-ton mooring spud, dropped from a towing vessel Miss Megan. The uninspected vessel was pushing two barges, a construction barge, Athena 106, and the unmanned deck barge, IBR 234, through the West Cote Blanche Bay oil field in St. Mary Parish, Louisiana. The aft spud on Athena 106 was released from its fully raised position and struck the buried gas pipeline in the northwest area of the oil field. (Spuds were used to keep the barges stationary and hold them in place during marine construction work). The released gas was ignited and the subsequent fire engulfed both the towing vessel and the two barges. Five out of eight people onboard, including the master and four barge workers were killed and one barge worker was reported missing. Following the investigation conducted by NTSB, the cause of the accident was ascribed to the failure of the owner of Athena



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LNG INCIDENTS REVIEW

06/03/2025

106, Athena Construction and the master and owner of Miss Megan, Central Boat Rentals to ensure the spuds were pinned securely on its barges before getting under way.”

3. British North Sea, Elgin Platform (2012) – Mechanical failure

“In March 2012, a gas leak occurred on the Elgin offshore platform, operated by Total, in the North Sea. This leak released a significant amount of gas, mainly methane, into the atmosphere. This break is due to unpredictable corrosion. The incident lasted several weeks before the leak was stopped. Although this event did not involve a ship, it illustrates the risks associated with offshore gas production facilities. “

4. Gulf of Mexico (2021) - unknown

“A leak in an underwater gas pipe sparked a swirling fire that raged for hours in the Gulf of Mexico. The circular inferno formed at 5:15 a.m. after a pipeline about 12 inches in diameter leaked, according to a statement from Petróleos Mexicanos, and Pemex, Mexico’s state-owned oil monopoly, which controls the pipeline.”

5. Baltic sea (2022) - Sabotage

“On September 26, 2022, the sabotage of the Nord Stream gas pipelines involved an underwater explosion damaged the Nord Stream 1 and 2 gas pipelines in the Baltic Sea, resulting in significant natural gas leaks. Although these gas pipelines are not shipping, this maritime incident led to massive releases of methane into the marine environment. “

6. Baltic Sea (2023) - Dropped object

“The damage to the Balticconnector gas pipeline between Finland and Estonia was not caused by the normal gas transmission process, Finnish transmission system operator (TSO) Gasgrid reported following the launch of an investigation into a leak. Damage to a Baltic Sea gas pipeline is believed to have been caused by a ship dragging a large anchor along the seabed, but it was too early to tell if this was an accident or a deliberate act, Finnish police said on Tuesday. Investigators said they had now retrieved a lost anchor from the seabed location where the pipeline ruptured on Oct. 8, and were investigating whether it belonged to a Chinese container vessel.”



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3.1.Synthesis of accidental review

the substantial growth in the LNG market since 1965 have been numerous studies that include information on potential risk associated with LNG production, handling and storage. These studies clearly show have generally agreed that LNG remains a high hazard substance. This review on LNG accidents on industrial site, maritime transport and pipeline transport highlighted how they might provide evidence for the debate surrounding LNG accident risk. The review found a total of 5 major incidents or accidents associated with LNG since 1944.

Of the 64 accidents analysed, 12 (19%) were due to accidents in industry, 42 (71%) were related to LNG transport ships and 6 (10%) were related to the transport of LNG by submarine pipeline (Figure 2)

Figure 2 shows the evolution of the number of accidents involving LNG on industrial sites, maritime transport and submarine pipelines since 1944. There has been a clear increase in the number of pipeline accidents since 2021, which may be related to acts of sabotage on pipelines in the Baltic Sea in connection with the current geopolitical context. A cyclical trend in the number of accidents involving LNG shipping between 1965 and 2015, with a clear decrease in accidents since 2015 and a relatively low number of accidents for industrial sites. LNG carriers are well designed and well maintained, which reduces the risk and severity of incidents. Their design prevents breaches in the cargo tanks and the involvement of several tanks in accidents. Potential risks may arise from the ignition of an LNG pool fire or a vapor cloud.

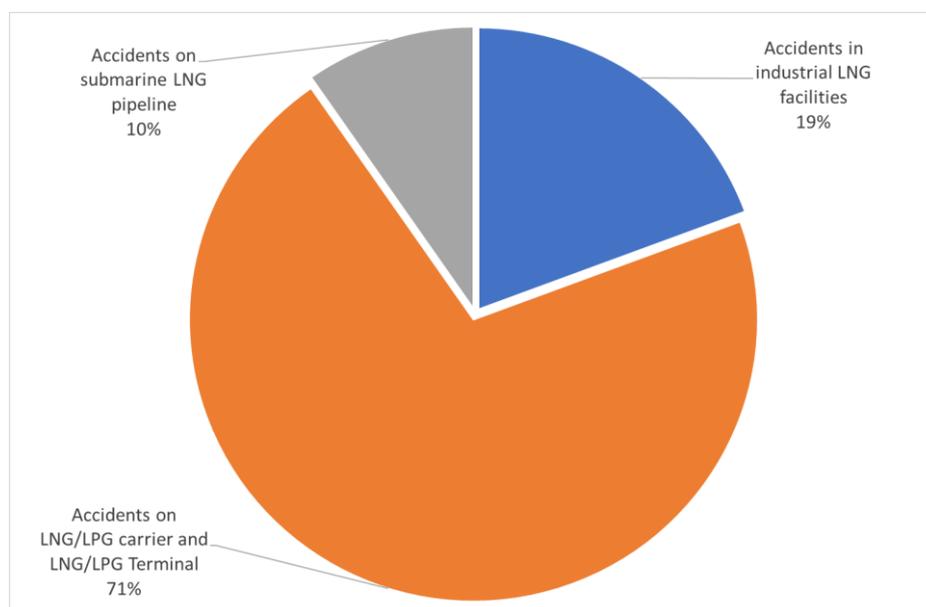


Figure 2: Analysis of the number of LNG-related accidents involving industrial sites, maritime transportation and transportation via submarine pipelines



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06/03/2025

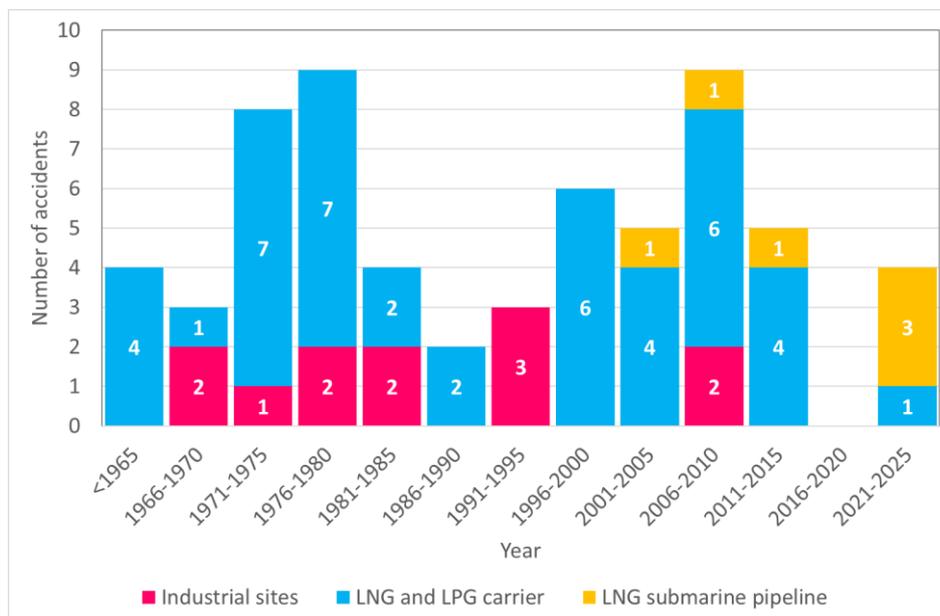


Figure 3: Evolution of the number of accidents involving LNG or LPG until 1944.

The Figure 4 presents the distribution of causes of accidents involving LNG for Industrial sites, LNG and LPG carrier and Terminal and LNG and Submarine Pipeline. Incidents resulting from human error, equipment failure or both can occur in any sector and any facility. In LNG terminal facilities, they can occur during loading (9%) unloading (7%), and stages of stages of production and transportation.

Furthermore, the analysis of causes for LNG shipping accidents clearly shows that the main causes of accidents are essentially collisions (21%) and mechanical problems (21%), followed by groundings (9%), loading phase (9%), external event (9%) and unloading phase (7%). LNG facilities and ships have advanced monitoring and control systems that make an incident unlikely compared to other releases. The consequences of most potential incidents would be contained on site and managed before they cause significant damage.

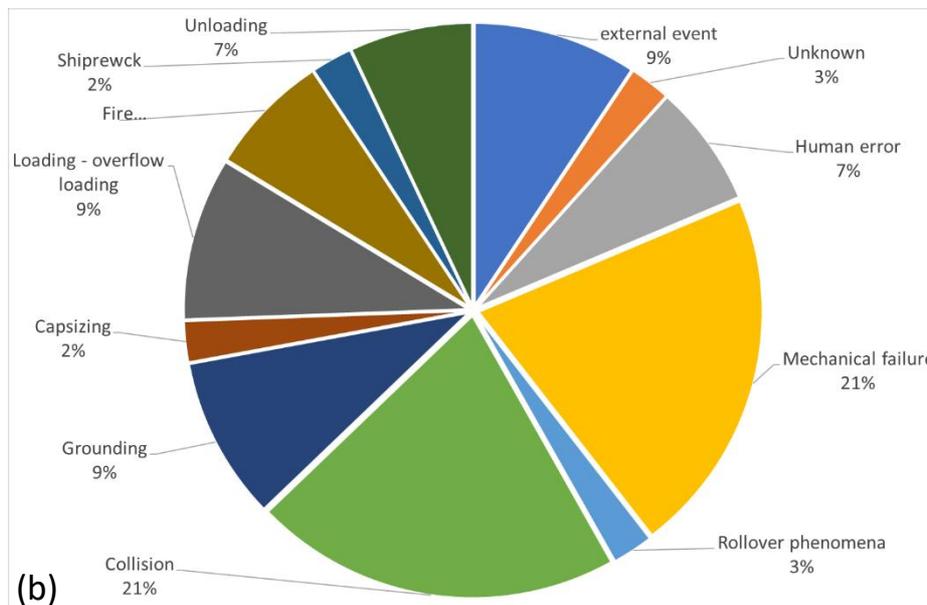
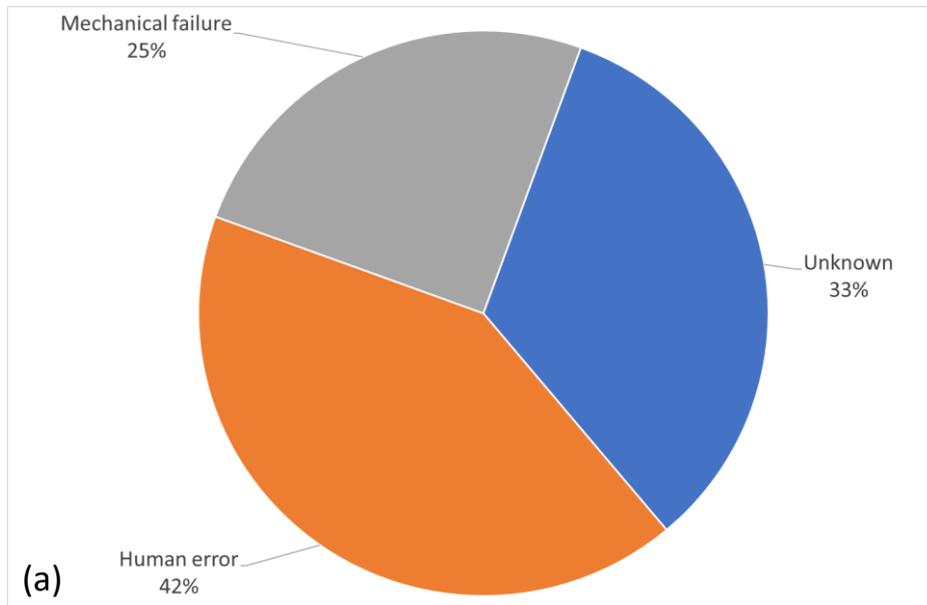
As regards the transportation of LNG by pipeline, the causes of the fewer accidents that have occurred are divided between mechanical problems (17%), human error (17%), or unknown origin (16%). However, since the evolution of the global geopolitical context and the strategic aspect, from an energy point of view, there has been an increase in the number of sabotage (17%) or dropped objects (33%) whether voluntary or involuntary which encourages vigilance and the strengthening of security measures around these transportation systems



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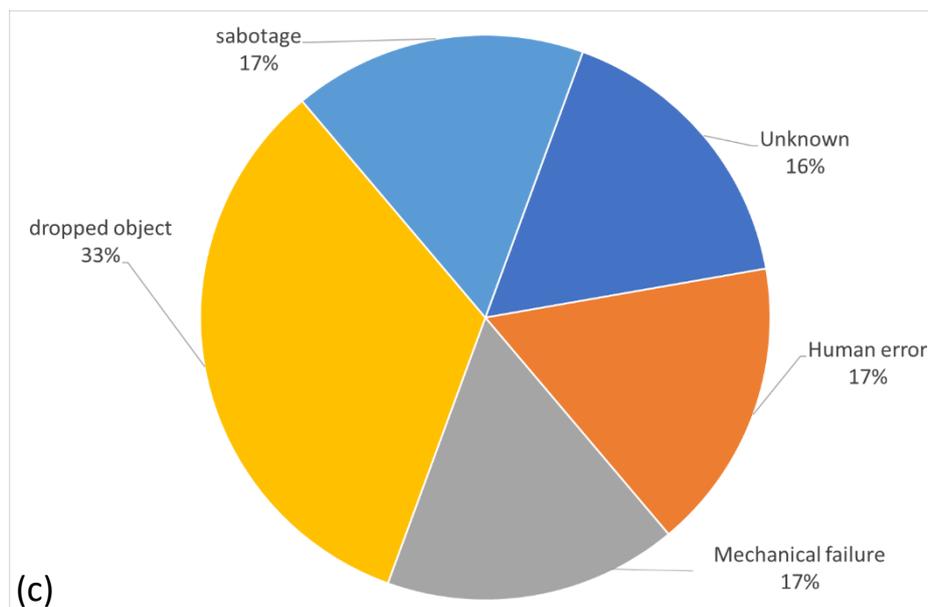


Figure 4: Distribution of causes of accidents involving LNG for a) Industrial sites, b) LNG and LPG carrier and Terminal c) LNG and Submarine Pipeline

3.2. Conclusion

This document, produced by the EU-funded MANIFESTS-Genius project, examines past accidents involving liquefied natural gas (LNG). The main objective is to learn from these incidents that occurred in industrial facilities, during maritime transport and on submarine pipelines. This analysis aims to improve preparedness and response to future coastal and marine pollution incidents involving gases.

The report also describes the chemical properties and hazards associated with LNG, providing essential context for understanding the risks of accidents. By identifying and analyzing these events, MANIFESTS-Genius seeks to strengthen coordination between the various authorities and organizations responsible for managing maritime and land incidents.

With regard to LNG carriers and the transportation of LNG by pipeline, the accidents at sea that have occurred in 60 years have resulted in very few major accidents. The history of the LNG industry shows that maritime incidents involving serious LNG spills are very rare. On the other hand, accidents involving LNG releases at terminals have resulted in serious accidents with loss of life, for example in Cleveland, Ohio (1944, 128 victims), Cove Point, Maryland (1919, 1 victim), and Skikda, Algeria (2004, 27 victims). As mentioned in [13] despite advances in safety knowledge, LNG remains a high hazard substance and adequate control is only partially achieved through improvements in technology and standards. A large portion of control measures are dependent on the proper design and execution of safety procedures, a well-functioning safety



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LNG INCIDENTS REVIEW

06/03/2025

management system, and a risk assessment that incorporates a full understanding of scenarios and their potential impacts.

The current geopolitical context and tension surrounding energy issues call for vigilance with regard to these industrial LNG production and transportation systems, with a focus on increasing surveillance and security measures to reduce the risks in the event of accidental spills.



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From Gases and Evaporators risk assessmeNt towards an Integrated management of sea and land pollution incidentS

MANIFESTS is a project co-funded by the European Union Civil Protection - DG-ECHO, developed in cooperation with RBINS, CETMAR, IMT Mines Alès, INTECMAR, IST, the UK Security Agency as associated partner and coordinated by Cedre.



Developing the Evidence Base for Public Health

Risks from Lithium Batteries in the Maritime



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Contents

EXECUTIVE SUMMARY	4
1. INTRODUCTION	5
1.1. Background	5
1.2. Aims and Objectives of the Study	7
2. METHODOLOGY	8
2.1. Incident Database Review	8
2.2. Scientific Literature Review.....	9
3. RESULTS AND DISCUSSION	10
3.1. Database Review	10
3.2. Scientific Literature Review.....	12
4. CONCLUSIONS AND RECOMMENDATIONS	14
5. REFERENCES.....	16
APPENDIX 1: Scientific Papers Reviewed	18
APPENDIX 2: Grey Literature Articles.....	19
APPENDIX 3: Search Terms.....	20



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Risks from Lithium Batteries, UKHSA

31/10/2024

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EXECUTIVE SUMMARY

- Lithium ion batteries (LIB) are rapidly becoming an important part of the maritime industry, both as cargo and within novel propulsion systems.
- Whilst offering great benefits as part of the drive for global decarbonisation, LIBs also pose potential hazards due to their thermal instability and potential to combust and produce highly toxic gases such as hydrogen fluoride (HF).
- As part of the MANIFESTS Genius project UK Health Security Agency (UKHSA) have undertaken a review of the evidence around LIB maritime incidents and their potential to impact public health.
- A review of maritime databases suggests that while incidents are relatively few at present, the trend may be rising, reflecting the increased presence of LIBs. Furthermore, accidents can be very serious due to the challenges associated with extinguishing LIB fires and their potential to reignite.
- Scientific studies of potential LIB hazards are similarly limited, although it does appear to be an emerging topic for research. Those studies that are available are mainly focussed on fire risks and do not consider off-gassing before ignition. None specifically considered implications to public health. A number of operational and environmental risk factors were identified as potential causes of LIB incidents.
- As with land-based incidents, public health protection from long running LIB fires in ports or at sea can be achieved by existing principles of shelter, evacuation, advice etc. However, this could become far more challenging where an LIB incident occurs within a vessel carrying passengers such as a ferry and some literature suggests incidents of this nature may already be occurring.
- In light of these findings, there appears to be a need for raised awareness among industry, responders and public health professionals regarding maritime incidents involving LIBs.



1. INTRODUCTION

Maritime transport is evolving significantly to meet the requirements of global emissions regulations, with new fuels and propulsion systems posing challenges for incident responders. The use of LIBs is one such development posing a number of challenges.

To better understand the current state of the art around response to LIBs a review of existing evidence of such incidents, their impacts and available actions to protect the safety and health of the public was undertaken.

This work represents Deliverable D3.1 of Work Package 3 of the MANIFESTS Genius project and was undertaken by UKHSA EHE Wales.

1.1. Background

LIB technology began development during the 1980's and 90's and now forms an essential part of the strategy for global decarbonisation¹. This is particularly well demonstrated by their increasing use in transportation. For example, statistics produced by Eurostat suggest numbers of battery only passenger cars (EVs) have risen across Europe from around 100,000 in 2013 to 3 million in 2022².

This demand for EVs likewise has led to the need for them to be transported to markets often by sea. Furthermore, the global strategy to reduce emissions has also impacted the ships themselves. According to the Alternative Fuels Insight platform, there are more than 800 battery ships in operation, a figure that has more than tripled in the past five years. Out of those, around 60% are known to be operating in Europe, using batteries on board for propulsion either in pure electric or hybrid functions³.

While battery technology offers great opportunity to reduce emissions, the technology also poses new hazards. LIBs have by far the highest energy densities of all battery types and contain flammable plastics and solvents. If the



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energy stored in a LIB is released rapidly, resistive, and chemical heating can result in thermal runaway, fire, and explosion.

LIBs operate sophisticated management systems to control the release of energy but if damaged, worn, or used incorrectly risks of thermal runaway can become a major issue with many reported incidents on land corroborating the dangers associated with this¹. As a LIB becomes unstable and overheats, it may emit flaming gases that present a thermal and toxic hazard. LIBs do not always combust immediately however⁴.

Overheating or fire may give rise to fluorinated decomposition and reaction products including large amounts of hydrogen fluoride (HF) as well as carbon monoxide, nitrogen oxides, hydrogen cyanide and hydrogen chloride⁵.

Chemical	% of vapour cloud	Behaviour (at 20 °C)
Carbon monoxide (CO)	38 %	When released, the gas will be lighter than air (buoyant) and will easily disperse in open or well-ventilated areas.
Benzene (C ₆ H ₆)	14 %	When released, the gas will be denser than air and will sit above the ground/sea surface.
Nitrogen dioxide (NO ₂)	10 %	When released, the gas will be denser than air and will sit above the ground/sea surface.
Hydrogen chloride (HCl)	10 %	When released, the gas will be denser than air and will sit above the ground/sea surface.
Hydrogen fluoride (HF)	4 %	When released, the gas will be lighter than air (buoyant) and will easily disperse in open or well-ventilated areas
Hydrogen cyanide (HCN)	< 1 %	When released, the gas will be lighter than air (buoyant) and will easily disperse in open or well-ventilated areas
Toluene (C ₇ H ₈)	4 %	When released, the gas will be denser than air and will sit above the ground/sea surface.

Table 1 – Indicative volumes and behaviour of primary gases of concern from LIBs⁶.

As well as thermal hazards, all of the above gases are toxic posing potential health effects following exposure. As such incidents involving LIBs pose potential public health risks.



A number of other gases may also be reportedly released depending upon specific battery types and construction materials and can include hydrogen, methane, ethane, carbon dioxide, propene, phosphorus oxyfluoride, ethyl fluoride, propylene⁷.

A study of 2017 identified several fluoride compounds generated during off gassing as intermediates, which further react with water ultimately generating HF. Tests undertaken in the study indicated that up to 20kg of HF can be generated from a LIB pack representative of an electric vehicle and up to 200 kg from a small energy storage system the likes of which could be present within a battery powered vessel, posing potential risks to human health⁸.

1.2. Aims and Objectives of the Study

The aim of this review was to establish the current evidence around maritime incidents involving LIBs and their potential for impact to public health. Specific objectives were defined to identify evidence detailing:

- The types and frequency of incidents,
- The types of vessels involved,
- The impacts / outcomes of incidents on public health,
- Protective actions undertaken,
- Any processes proposed or used around decision making for such actions.



2. METHODOLOGY

2.1. Incident Database Review

Several key international maritime accident databases were reviewed for a period from 2013 up to 2023 (Table 2).

Source	Description	Link
International Maritime Organisation (IMO)	Database of Global Annual Maritime Accident Statistics	https://www.imo.org/en/OurWork/MSAS/Pages/Casualties.aspx
European Maritime Safety Agency (EMSA)	Database of EU Annual Maritime Accident Statistics and trends	https://data.europa.eu/euodp/en/data/dataset/accident-investigation-emcip
National Oceanic and Atmospheric Administration (NOAA)	Database of maritime and transport incidents primarily in USA	https://incidentnews.noaa.gov/raw/index
US Coastguard	Marine Casualty & Pollution Data for Researchers	https://www.dco.uscg.mil/Our-Organization/Assistant-Commandant-for-Prevention-Policy-CG-5P/Inspections-Compliance-CG-5PC-/Office-of-Investigations-Casualty-Analysis/Marine-Casualty-and-Pollution-Data-for-Researchers/
Allianz (insurers)	Global incident statistics	https://www.agcs.allianz.com/news-and-insights/reports/shipping-safety.html
Public Health England Database (CIRIS)	Chemical incident database for UK and ROI	In-house access only
Industry Bulletins and Newsletters		https://www.maritimebulletin.net/ https://www.fleetmon.com/maritime-news/?year=2020&category=incidents https://safety4sea.com/23073-maritime-casualties-and-incidents-reported-in-2019/

Table 2: Industry and Regulatory Database Sources Accessed for Review

Accident databases were reviewed to assess the total incidents reported annually and searched for key words, namely, *battery*, *batteries*, *lithium*, *lithium-ion*, *l-ion* and combinations of these.

Resulting incidents were assessed for trends over time, incident type, vessels involved and incident location. Results of the search are presented in section 3.1



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2.2. Scientific Literature Review

A literature review of relevant published scientific papers was undertaken with the assistance of UKHSA Library Services.

An Annotated Bibliography search was undertaken using a defined search question as below:

“Studies in respect of maritime shipping and port accidents involving lithium batteries and resulting in protective actions for the general public”.

Full details of the search strategy are presented in Appendix 3

Returned abstracts were screened for:

- Relevance to the scope of the study (Section 1.2)
- Availability of the full paper in English

“Grey” literature was also included in the search and reviewed against the same criteria. Grey Literature included the following categories:

- Incident reports
- Investigations
- Guidance
- Comment / Editorials
- Overviews
- News articles

Results of the review are presented in Section 3.2.



3. RESULTS AND DISCUSSION

3.1. Database Review

Based upon the key words used, 10 incidents were identified over the search period. Whilst only a limited number of incidents were found the results indicate an upward trend (Figure 1). Incidents reported in media were also noted to be increasing (Section 3.2).

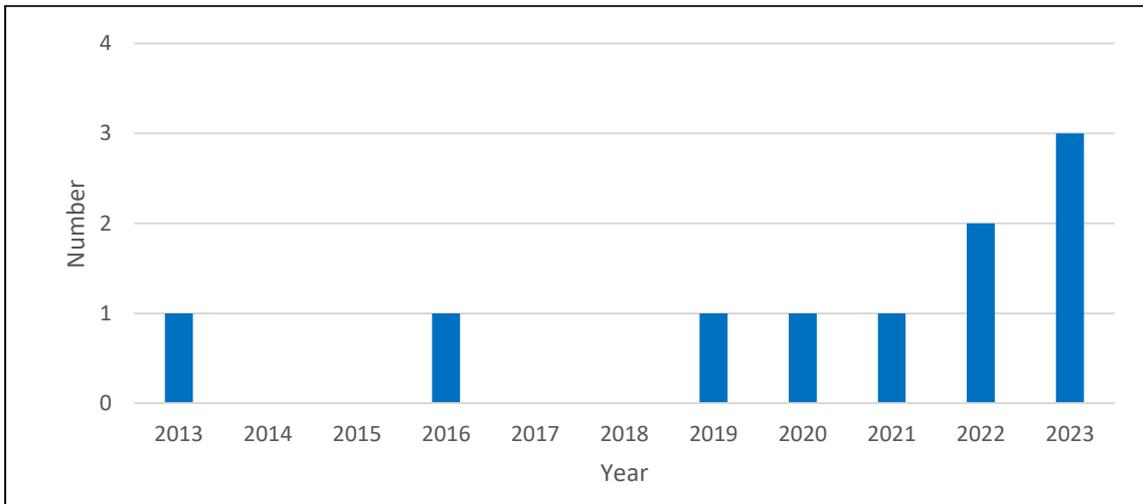


Figure 1. Annual number of batteries / lithium batteries incidents from 2013 to 2023.

Of the 10 incidents identified the majority appeared to be in open sea, whilst the vessels involved appeared to be an even split between container ships, car carriers and ferries (RoRo (vehicles cargo) / RoPax (vehicles and passengers))

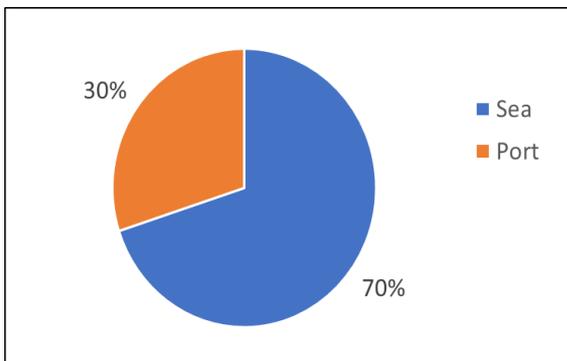


Figure 2. Incident location.

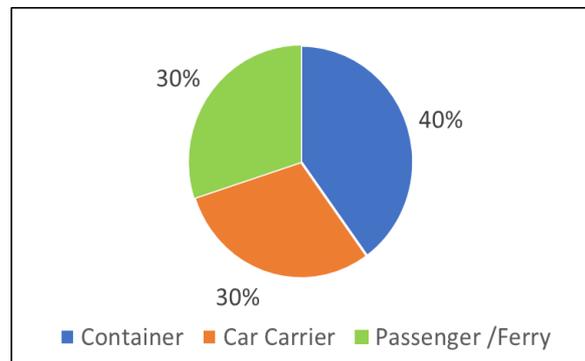


Figure 3. Vessel type

Land based incidents show similarly rising trends. Data provided by UK fire services suggest a 46% increase in incidents in 2023 compared to 2022⁹. Likewise, data from a number of EU countries between 2018 and 2022 suggest consistent increases in numbers of electric car fires as more enter service¹⁰.

A review of UKHSA incident records similarly illustrates this trend (Figure 4).

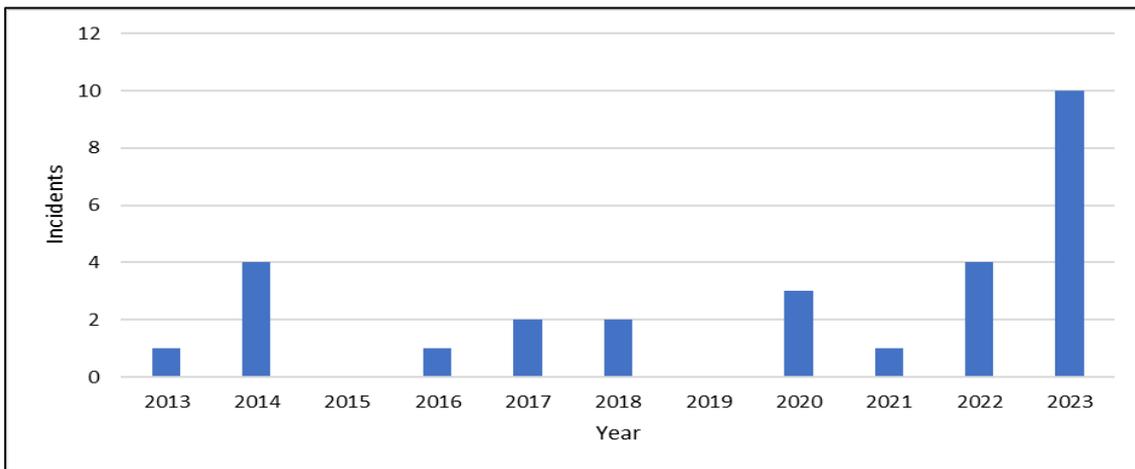


Figure 4: Incidents by year reported to UKHSA,.

Incidents covered a wide range of activities and scenarios reflecting the increasing presence of LIB (Figure 5). Most related to fires but some also reported off-gassing. For example, a faulty mobile phone battery at a retail store released fumes with reported health effects immediately following exposure, highlighting the potential hazards associated with off-gassing.

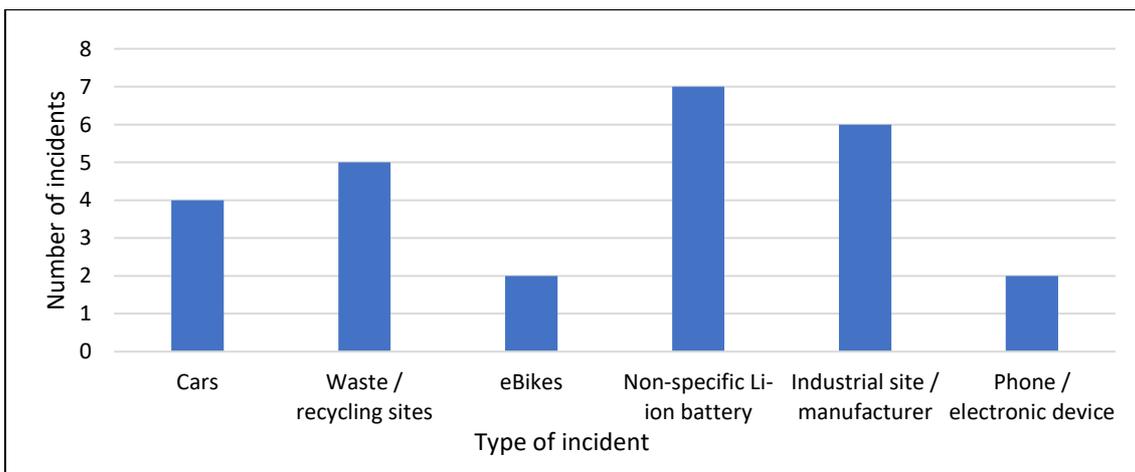


Figure 5: Type of incidents reported by UKHSA, over the search period.

3.2. Scientific Literature Review

A total of 14 abstracts were returned from the search undertaken (Appendix 1) and reviewed against the criteria listed in Section 2. Most papers were published between 2017 and 2024 reflecting how this is a relatively new and developing area of research.

The papers covered a range of aspects associated with battery hazards on board ships, including design, safety analysis and response to fires. No papers specifically considered public health, but several did identify risks to passengers and crews via case studies.

Papers identified a number of factors affecting battery safety including humidity, wear, charging levels, age and storage¹¹. Salt water was also identified as a factor affecting battery safety¹² as noted in a US Coastguard advisory document¹³.

The main hazard in all papers was identified as fire / explosion, with most referencing the challenges and uncertainty of how best to extinguish these types of fires. Only one study (from Grey Literature) considered off-gassing of HF and its potential health risks from skin absorption, concluding that more work is needed on this topic¹³. HF can have delayed effects so impact from exposure may not be immediately apparent¹⁴.

Several case studies were identified in the papers. Almeida *et al*¹⁵ outlined recent incidents on car carrier ships *Felicity Ace* (2022) and *Freemantle Highway* (2023).

The *Fremantle Highway*, a car carrier loaded with more than 3,700 vehicles including 500 electric vehicles on board, caught fire on July 25, 2023, while sailing off the coast of the Netherlands. Unable to extinguish the fire, the crew abandoned ship. One crewmember died. The fire burned for days destroying more than 2,000 vehicles and several decks before it burned itself out. The hulk was towed into the Dutch port of Eemshaven. The cause of the fire remains uncertain but underlines the difficulties of tackling vehicle fires on board ships¹⁶.



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31/10/2024

On 16 February 2022, the *Felicity Ace*, a car carrier with approximately 4,000 vehicles (around 100 being electric), suffered a fire while transiting the Atlantic. The ship's crew evacuated, and no injuries were reported. However, the fire persisted for two weeks, and on 1 March 2022 the vessel sank. The estimated value of the vehicles on board was estimated at around \$401 million. Although, the exact cause of the fire was not determined, it is believed that the lithium batteries in some of the electric vehicles made it difficult to control and extinguish the fire, again highlighted the unique challenges presented by electric vehicle shipping.

Almeida *et al*¹⁵ also identified statistics suggesting over 300 incidents on ferries. While no detail on the scale or nature of these incidents was reported, it indicates such incidents are an increasing threat with potential for impacts to passengers and crew on these vessels.

All papers identified the need for improved guidance, management and training for LIBs within the maritime industry and the need for more research, particularly around firefighting.

Grey Literature returned 47 items varying in relevance to the study. A large percentage of returns related to industry media articles describing incidents or new guidance (Appendix 2). A number of risk factors were identified as potential sources of fires including transport of older electric vehicles and misidentification of LIBs in containerised cargo.



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4. CONCLUSIONS AND RECOMMENDATIONS

UKHSA have undertaken a literature review around emerging hazards from LIBs within the maritime transport sector and their potential impacts upon public health.

While accident databases have reported only a limited number of incidents to date, numbers appear to be showing an upward trend, possibly reflecting the increasing occurrence of LIBs as both cargo and propulsion methods.

The main hazard posed by LIBs is their instability which can lead to fire and explosion as well as significant off gassing of toxic chemicals. A number of causes of instability have been defined, including, age and condition of LIBs, level of charge and damage as well as environmental factors including storage, temperature, humidity and salt water. All of these are relevant to the maritime transport / operational environment.

LIB fires pose severe challenges to conventional fire fighting techniques resulting in long running incidents with risks of reignition. This has been illustrated by reported maritime incidents involving LIBs where vessels have been severely damaged and where crews and responders have been impacted, in some cases with fatal effects.

As this is an emerging threat current scientific literature is limited but is becoming an area of intense research. A raft of new guidance is being developed around transport and use of LIB on ships, although little appears to relate to their public health impacts.

As with land-based LIB incidents, public health protection from long running LIB fires in ports or at sea can be achieved by existing principles of shelter, evacuation, advice etc. However, this could become far more challenging where an LIB incident occurs on-board a vessel carrying passengers, where shelter and evacuation options may be more limited or non-existent.



In this respect it is concluded that specific consideration should be given to potential incidents on ferries where LIBs are becoming a viable propulsion in new vessel designs and where passengers and vehicles are present together on open car decks with limited options to regulate private EVs.

In these scenarios it is not only possible for passengers to be exposed to smoke and heat from the fires but also to harmful gases emitted before ignition. It is reported that some ferry operators are already prohibiting carriage of EVs in Scandinavia¹⁷.

In light of these conclusions, there appears to be a need for raised awareness among industry, responders and public health professionals regarding incidents involving LIBs.

Operationally this is being reflected by industry guidance such as that developed by EMSA¹⁸, but this awareness should also consider wider elements of response and public health. In this latter area we would recommend

- Consideration of specific detection for gases of concern and fire particularly as it has been reported that off-gassing can absorb infra-red causing false negative results from thermal detection systems used by responders¹⁹.
- Information and training for public health responders to be aware of the potential health impacts / delayed effects of gas exposure, ensuring that passengers are registered, triaged, and followed up where necessary.

It is hoped that the work and deliverables of the MANIFESTS Genius project will contribute to the awareness and management of the risks from LIBs to relevant international stakeholders and improve safety and response to emerging maritime technologies.



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Risks from Lithium Batteries, UKHSA

31/10/2024

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APPENDIX 1: Scientific Papers Reviewed

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APPENDIX 2: Grey Literature Articles

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APPENDIX 3: Search Terms

Search terms were developed from results retrieved from a scoping search.

Age group	Language	Publication type	Time limit	Geography
	English			

Database / Search strategies

SCOPUS

(TITLE-ABS-KEY ((lithium OR lithium-ion OR lithiumion OR "lithium ion") W/3 batter*)) AND (TITLE-ABS-KEY (maritime OR ship* OR ferry OR ferries OR harbour* OR harbor* OR dock OR docks OR jetty OR jetties OR port OR ports OR seaport* OR marina* OR coast* OR shore* OR beach*)) AND ((TITLE-ABS-KEY (incident* OR accident* OR emergenc* OR emission* OR explosi* OR fire* OR fumes OR gas* OR smoke)) OR (TITLE-ABS-KEY (casualt* OR injur* OR death* OR mortalit* OR burn* OR poison*)) OR (TITLE-ABS-KEY (health PRE/1 (impact* OR effect* OR hazard*))) OR (TITLE-ABS-KEY ("population risk*")) OR (TITLE-ABS-KEY (shelter* OR evacuat*)) OR (TITLE-ABS-KEY ((emergency OR incident) PRE/1 (preparedness OR procedure OR response))) OR (TITLE-ABS-KEY ("lessons learned"))) AND (LIMIT-TO (LANGUAGE , "English")))

WEB OF SCIENCE

TS=((lithium or lithium-ion or lithiumion or "lithium ion") NEAR/3 batter*) and Preprint Citation Index (Exclude – Database)

AND

TS=(maritime or ship* or ferry or ferries or boat* or harbo?r* or dock or docks or jetty or jetties or port or ports or seaport* or marina* or coast* or shore* or beach*) and Preprint Citation Index (Exclude – Database)

AND

(((((TS=((incident* or accident* or emergenc* or emission* or explosi* or fire* or fumes or gas* or smoke))) OR TS=((casualt* or injur* or death* or mortalit* or burn* or poison*))) OR TS=(health NEAR/1 (impact* or effect* or hazard*))) OR TS=((shelter* or evacuat*))) OR TS=((emergency or incident) NEAR/1 (preparedness or procedure or response))) OR TS=("lessons learned") and Preprint Citation Index (Exclude – Database)

Included: English, all databases

EXCLUDED: Patents

Embase

1. ((lithium or lithium-ion or lithiumion or "lithium ion") adj3 batter*).ti,ab,kw.
2. ship/
3. seashore/
4. (maritime or ship* or ferry or ferries or boat* or harbo?r* or dock or docks or jetty or jetties or port or ports or seaport* or marina* or coast* or shore* or beach*).ti,ab,kw.



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5. or/2-4
6. exp "accidents and accident related phenomena"/
7. exp "fire and fire related phenomena"/
8. (incident* or accident* or emergenc* or emission* or explosi* or fire* or fumes or gas* or smoke).ti,ab,kw.
9. exp injury/
10. exp burn/
11. gas poisoning/
12. accidental death/
13. (casualt* or injur* or death* or mortalit* or burn* or poison*).ti,ab,kw.
14. (health adj (impact* or effect* or hazard*)).ti,ab,kw.
15. population risk*.ti,ab,kw.
16. emergency evacuation/ or emergency shelter/
17. (shelter* or evacuat*).ti,ab,kw.
18. ((emergency or incident) adj (preparedness or procedure or response)).ti,ab,kw.
19. "lessons learned".ti,ab,kw.
20. or/6-19
21. 1 and 5 and 20

Medline

1. ((lithium or lithium-ion or lithiumion or "lithium ion") adj3 batter*).ti,ab,kw.
2. Ships/
3. (maritime or ship* or ferry or ferries or boat* or harbo?r* or dock or docks or jetty or jetties or port or ports or seaport* or marina* or coast* or shore* or beach*).ti,ab,kw.
4. or/2-3
5. exp Accidents/
6. Mass Casualty Incidents/
7. explosions/ or exp fires/
8. exp Smoke/
9. (incident* or accident* or emergenc* or emission* or explosi* or fire* or fumes or gas* or smoke).ti,ab,kw.



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31/10/2024

10. exp "Wounds and Injuries"/
11. exp Gas Poisoning/
12. asphyxia/
13. exp Mortality/ or death/
14. (casualt* or injur* or death* or mortalit* or burn* or poison*).ti,ab,kw.
15. (health adj (impact* or effect* or hazard*)).ti,ab,kw.
16. population risk*.ti,ab,kw.
17. emergencies/ or emergency shelter/
18. (shelter* or evacuat*).ti,ab,kw.
19. ((emergency or incident) adj (preparedness or procedure or response)).ti,ab,kw.
20. "lessons learned".ti,ab,kw.
21. or/5-20
22. 1 and 4 and 21



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