WP2 – Enhancing knowledge and data on gases and evaporators

D2.1 – Literature review on past accident

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Co-funded by the European Union Civil Protection

ACKNOWLEDGEMENT

The work described in this report was supported by the Directorate-General for European Civil Protection and Humanitarian Aid Operations (DG-ECHO) of the European Union through the Grant Agreement number 101004912 - MANIFESTS – UCPM-2020-PP-AG, corresponding to the Call objective "Enhancing prevention and protection from the effects of maritime disasters" under priority 1: "Developing response capacity for marine pollution".

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Project Acronym	**MANIFESTS**
Project Full Title	**MAN**aging risks and **I**mpacts **F**rom **E**vaporating and gaseous **S**ubstances To population **S**afety
Gant Agreement Nr.	**101004912**
Project Website	**https://www.manifests-project.eu/**

Deliverable Nr.	**D2.1**
Status (Final/Draft/Revised)	**Draft**
Work Package	**WP2**
Task Number	**2.1**
Responsible Institute	**Laurent APRIN, ARMINES**
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Recommended Citation	
Dissemination Level	**Public**

Document History			
Version	**Date**	**Modification Introduced**	
		Modification Reason	**Modified by**
1	05/07/2021	Skeleton & content	L. APRIN
1.1	05/07/2021	Revision & comments	Cedre

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1. Introduction

Maritime transport of Hazardous and Noxious Substances (HNS) has increased for 20 years, involving the risk of major pollution accidents with potentially more hazardous than oil. Chemicals may involve long-term environmental effects and the risks for public safety can be more severe for chemical releases (European Maritime Safety Agency [EMSA], 2007). Approximately 2,000 chemicals are transported by sea and only a few hundred chemicals are transported in bulk, but it represents the main volume of the chemical trade (Purnell, 2009).

Alongside the expansion of chemicals transported at sea, incidents involving chemical tankers increased accordingly. Still, information on past and more recent incidents is not easily available. Furthermore, in the case of marine accident involving HNS, spill response is difficult due to the chemicals spilled, particularly when gas or volatile substances are released. The vapour cloud created can be toxic, flammable or explosive and there is a necessity to protect the crew, the population nearby as well as the environment and the stakeholders involved in marine pollution response. As an example, Figure 1 shows a picture of the explosion which occurred in September 2019 in the Ulsan harbour, South Korea. This explosion is the consequence of a styrene monomer leak on the chemical tanker Stolt Groenland that led to a massive explosion with fireball and mushroom cloud.

Figure 1: Fireball and mushroom cloud at the Port of Ulsan, following the explosion of styrene monomer carried out in the chemical tanker Stolt Groenland (South Korea) in September 2019.

The present report is a literature review on past accidents that have induced the formation of a toxic, flammable or explosive gas cloud. The information gathered will allow better identification of

1) the categories of chemicals most involved; 2) the main risks generated by the gas cloud dispersion in the air and 3) the consequences of a chemical slick on fire at the water surface as well as the hazard due to a vapour cloud explosion.

This work is part of WP2: Enhancing knowledge and data on gases and evaporators of the MANIFESTS program (Managing risks and impacts from evaporating and gaseous substances to population safety) that studies risks associated to accidental chemical spills in the marine environment. The aim of this WP is to contribute to a better prediction of the consequences of vapour clouds due to marine accidents. This would facilitate the intervention of marine pollution organisms and would also help to protect population nearby, as we would know precisely where the dangerous area is.

2. Review of past accidents

2.1. HNS accidents

From 1947 to 2012, 101 maritime accidents resulting in chemical pollution have been identified around the world (Cedre, Internet, Press). The analysis of these accidents shows that chemical tankers and cargo are the most often involved ships in marine accident leading to a chemical spill at sea. In addition to this analysis, the investigation of the packaging type of chemicals spilled at sea shows that the majority of chemical pollution is due to the rupture of the tanks of ships following a collision, grounding or an explosion on board. This type of accident, which is the most frequent, is generally the cause of a large spill of chemicals at sea and, as a result, the source of major pollution. The packaging in barrels, cylinders or small tanks comes in second position. These packages are most often transported on board freighters and container ships, and accidents correspond to losses at sea of these drums following unfavourable weather-ocean conditions.

The analysis of maritime accidents also dealt with the chemical nature of the substances involved. The following table lists the most representative chemicals that have been spilled in accidents that have occurred over the past 50 years. For each chemical listed, the behaviour into the marine environment is determined from the European classification resulting from the SEBC code (*). This table highlights the importance of evaporating chemicals in marine accidents.

Chemical	SEBC code(*)
Methyl Tert-Butyl Ether	ED
Butylene	D
Nitric Acid	D
Phosphoric Acid	D
Methanol	DE
Ethanol	D
Ammonium Nitrate	D
Sulfuric Acid	D
Acrylonitrile	DE
Phenol	S
Hydrochloric Acid	D
Ammonia Anhydrous	DE
Sodium Chlorate	D
Palm Oil	F
Naphtha	FE
Xylene	FE

Table 1 : Most implicated chemicals in marine spills accident.

The United States and Canada have also analyzed marine accidents involving chemicals. These analyses, performed by US Coast Gard and Fingas respectively in 1999 and 2001, are summarized in Table 2 and Table 3.

These tables show that the chemicals implicated in marine spill are different between US and Canada and only sulfuric acid and sodium hydroxide appear in both lists. This analysis of maritime accidents also highlighted the following points:

- US are more impacted than Canada by chemicals that evaporate;
- Accidental spills of chemicals at sea mainly take place from ships specializing in transporting chemicals (38%) and from cargo ships (35%);
- In 66% of cases, spills originate from leaks in vessel tanks;
- Among the multitude of substances transported daily, sulfuric acid is the chemical most involved in accidents both in terms of frequency and in terms of quantities spilled.

Very schematically, it is possible to discern two types of risks linked to chemical incidents, in a certain way independently of the form of maritime transport of products, in bulk or in packages: those affecting people (crew, emergency people, surrounding population) and those relating more specifically to the environment.

(*) Code SEBC : Standardized European Behaviour Classification System Codes permet de classer les substances chimiques. D : Dissolver, S : Sinker (coulant), F : Floater, E : Evaporator

U S (US Coast Guard, 1999)	
Chemical	**SEBC code**
Sulfuric acid	D
Toluene	E
Sodium hydroxide	D
Benzene	E
Styrene	FE
Acrylonitrile	DE
Xylene	FE
Vinyl acetate	ED
Phosphoric acid	D

Table 2 : Most implicated chemicals in marine spills accident for US.

Canada (Fingas, 2001)	
Chemical	**SEBC code**
Sulfuric acid	D
Hydrochloric acid	D
Ethylene glycol	D
Sodium hydroxide	D
Ammonia anhydrous	DE
Nitric acid	D
Chlorine	G
Ammonium hydroxide	D
Sulfuric acid	D

Table 3 : Most implicated chemicals in marine spills accident for Canada.

2.2. Review of accidents involving evaporating chemicals

This chapter is devoted to specific incidents or accidents involving volatile chemicals. This review aims to help the understanding of the causes of incidents but also to identify the most involved volatile chemicals in those marine accidents. This will enable to define the list of chemicals for the experimental laboratory tests to be performed in the MANIFESTS project. For all the accident analysed, the framework used is as follows:

- General information: date, location, cause of the incident and a brief description;

- Information on the pollutant such as its nature, quantity spilled and how it was transported (in tanks, in bulk…);
- Risks associated to those substances.

2.3. Description of accidents

2.3.1. YUYO MARU

The accident of Japanese gas carrier Yuyo Maru No. 10 occured on November 9, 1974 on a route between Saudi Arabia and the city of Kawasaki in Japan. On arrival in Tokyo Bay, the Yuyo Maru No. 10 was filled with propane, butane and naphtha and collided with the ship Pacific Ares. The collision resulted in a large hole in the hull that ignited and instantaneously exploded the naphtha that leaked from the ship and caused a fire on the seawater surface. Following the pool fire, the Pacific Ares was engulfed in flames and the fire spread to the ship. During the naphtha fire, five crew members of the Yuyo Maru No. 10 and 28 of the 29 Pacific Ares sailors were killed. Despite successive spill-related explosions, response services attempted to tow the Yuyo Maru No. 10 out of Tokyo Bay in order to limit the consequences. Despite the attempts, Yuyo Maru No. 10 sank by bombardment and torpedoes in the south of Nojima Saki.

Date: 09/11/1974	**Risks associated:**
Place: Japan, Tokyo bay	**Propane:**
Pollutant's type: propane, butane, naphtha	**H220** -extremely flammable gas
Packaging:	**H280** - contains pressurized gas - can explode if heated
Quantity spilled 202 tons of propane, 6 443 tons of butane and 20 831 tons of naphtha	**Butane:**
Cause of incident: collision	**H220** -extremely flammable gas
Components' vapour pressure (20°C):	**H280** - contains pressurized gas - can explode if heated
Propane: 8,3 kPa	**H340** - can induce genetic disorders
Butane: 2,1 kPa	
REFERENCES	**Naphtha** :
cedre.fr, 2009, Spills : Yuyo Maru N°10	**H225** -very flammable liquid and vapour
Fiche toxicologique INRS propane	**H304** - can be deadly in case of ingestion and penetration into the respiratory tract
Fiche toxicologique INRS butane	**H315** - causes skin irritation
Naphta léger (pétrole) - Carl Roth	**H336** - can cause dizziness and somnolence
	H411 - toxic for aquatic organisms, causes adverse effects long term

2.3.2. CAVTAT

On June 14, 1974, the Yugoslavian dry carrier Cavtat, which was carrying respectively 150 tons of tetramethyl lead (TML) in 500 drums on the ship's deck and 120 tons of in 400 drums located in the hold, collided with the Panamanian bulk carrier Lady Rita.

Tetramethyl lead is a colorless, oily, and highly toxic liquid that is a gasoline additive which is a major component of antiknock agent for fuels.

Following the collision, the ship's hull split open and made it impossible to tow and rescue the ship. 4 hours after the accident, the vessel sank in a depth of 94 m in Italian territorial waters causing the dispersion of the 400 TML drums on the main bottom of the vessel while the other drums around remained in the damaged vessel. After two years of political and media debates, the Italian parliament offered financial support for the bailout which was organized by the Italian oil company Saipem in April 1977. After work and $16 million in spending made for the recovery operation, 250 tons of TML were recovered (93% of the cargo) and 20 tons were lost. Following this shipwreck, a surveillance of the area was carried out and showed minor effects on the environment.

Date: 14/06/1974	**Risks associated:**
Place: Italy, open sea	**Tetraethyl lead:**
Pollutant's type: Tetraethyl lead and tetramethyl lead	**H300** - deadly in case of ingestion **H330** - deadly by inhalation
Packaging: drums	**H370** - confirmed risk of harmful effects for organs
Quantity spilled: 270 tons	Can cause skin and eye irritation
Cause of incident: collision	**Tetramethyl lead:**
	H226 - very flammable liquid and vapour
Components' vapour pressure (20°C):	**H301** - poisonous in case of ingestion
Tetraethyl lead: 0,027 kPa	**H331** - poisonous by inhalation
Tetramethyl lead: 3,2 kPa	**H372** - confirmed risk of harmful effects for organs following repeated exposure or extended exposure
REFERENCES	
Helcom response manual, volume 2, 2002	
Pubchem	
cedre.fr, 2009, Cavtat	
loostrom.com, CAVTAT	

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2.3.3. RENÉ 16

The accident of the Belgian oil tanker René 16 took place on January 16, 1976 in the port of Landskrona in Sweden. In the evening, during the phase of unloading the ammonia present in its tanks, the transfer pipe broke causing the dispersion of the ammonia on the quay despite the intervention of the personnel on the valve and on the compressor located on the quay. Following this spill, the firefighters acted very quickly and sprayed water on the ammonia cloud which surrounded the ship. The leak was brought under control after closing the valve on the ship and despite this intervention 180 tons of ammonia were dispersed from a nearby shipyard. Two members of the crew died during this accident due to pulmonary edema following the passage of the ammonia cloud. Investigations following the accident showed that the pipe used during the unloading was intended to transfer propane and butane. Ammonia being more corrosive, the pipe was destroyed which caused it to rupture.

Date: 16/01/1976	**Risks associated:**
Place: Sweden	**Ammonia:**
Pollutant's type: ammonia	**H221** - flammable gas
Packaging: tank container	**H314** - causes severe skin burns and eye lesions
Quantity spilled: 180 tons	**H331** - poisonous by inhalation
Cause of incident: human error, wrong choice of hose	**H400** - very poisonous for aquatic organisms
Components' vapour pressure (25°C):	
Ammonia: 999 kPa	

REFERENCES

Helcom response manual, volume 2, 2002

Fiche toxicologique INRS ammoniac

Loostrom.com, René 16

2.3.4. SINDBAD

On January 16, 1976, the Iraqi ship Sindbad lost its cargo during bad weather between Hamburg and Rotterdam at a depth of 25 to 30 meters. The lost cargo consisted of 51 steel cylinders each containing 1,000 kg of liquefied chlorine. The pressure in these storages was about 340 kPa at seafloor temperature, which is about 5° C. Research was undertaken to recover the tanks and in January 1980 5 cylinders were located by divers and recovered. Seven other vessels were found by fishermen over the following years. The state of corrosion of the recovered tanks showed a significant risk for the fishermen and all the users of the sea. Hence, the Dutch authorities decided a new response strategy and, in 1984, new investigations were carried out in the area where the

cisterns were lost. The tanks found were moved to safer areas and then destroyed by explosives. The authorities were able to observe the rise of chlorine in the water column and then its dispersion into the atmosphere. The use of ammonia created a reaction with chlorine which revealed a toxic cloud of ammonium chloride of 300 m wide, 300 m high and 3000 m long, instantly killing the birds flying in the cloud. This accident resulted in a total cost to the Dutch authorities of around $1 million.

Date: 16/01/1976	**Risks associated:**
Place: North Sea, Holland	**Chlorine:**
Pollutant's type: chlorine	**H270** - can cause or worsen a fire
Packaging: steel cylinders	**H315** - causes skin irritation
Quantity spilled: 51 tons	**H319** - causes severe eye irritation
Cause of incident: bad weather conditions	**H331** - poisonous by inhalation
Components' vapour pressure (20°C):	**H335** - can irritate the respiratory tract
Chlorine: 569 kPa	**H400** - very poisonous for aquatic organisms
REFERENCES	
Helcom response manual, volume 2, 2002	
Fiche toxicologique INRS chlore	
cedre.fr, 2009, Sindbad	
Loostrom.com, Sindbad	

2.3.5. FINNEAGLE

On October 1, 1980, the Swedish ro-ro ship Finneagle encountered difficult weather conditions on a journey from New Orleans in the United States to Valhamn in Sweden. These weather conditions prompted the displacement of a container containing trimethyl phosphite. Although secured by the crew, a leak emerged which turned into a fire and then an explosion. The intensity of the fire increased and triggered fire extinguishing systems which could not contain the blaze. Thermal radiation and the toxicity of gases and fumes have reached significant levels requiring the intervention of emergency services. The weather conditions being very difficult, the life boats could not be used by the passengers and the two helicopters dispatched to the site could not recover them. A more suitable helicopter will intervene a few hours later and collect 22 people. The burning ship was then towed to Lerwick in the Shetland Islands and it was not until 4 October 1980 that all the sources of fire were extinguished.

Date: 01/10/1980	**Risks associated:**
Place: North Sea, west of Orkney islands	**Trimethyl phosphite:**
Pollutant's type: Trimethyl phosphite	**H226** - very flammable liquid and vapour
Packaging: tank containers	**H302** - poisonous in case of ingestion
Quantity spilled: not available	**H315** - causes skin irritation
Cause of incident: structural damage	**H319** - causes severe eye irritation
Components' vapour pressure (20°C):	
Trimethyl phosphite: 3,2 kPa	

REFERENCES

Helcom response manual, volume 2, 2002

Wikipédia, Phosphite de triméthyl

INRS phosphite de triméthyl

2.3.6. BRIGITTA MONTANARI

On November 16, 1984, the Italian chemical tanker Brigitta Montanari sank in the Adriatic Sea near the town of Sibenik in Yugoslavia. The vessel was carrying 1,300 tons of vinyl chloride monomer (VCM), and sank to a depth of 82 m. Based on the safety conditions and technical feasibility, the maritime authorities decided to refloat the wreckage and pump the chemicals to avoid large-scale pollution. Rescue operations began in August 1987, assuming that the vinyl chloride monomer tanks had not been damaged. However, a VCM leak estimated at 1 kg/day was detected at the start of the operation. During the refloating operations, and in order to avoid the total rupture of the vessel, a 5 mm hole was drilled in the deck to release some of this chemical and control its release into the environment. Unfortunately, a significant VCM leak started (estimated at 3 tons/day) and vinyl chloride concentrations greater than 5 g/l were measured in the water column, 300 m from the wreckage. Operations were halted in the winter of 1987, and resumed in the spring of 1988. The wreckage was brought up to a depth of 55 m to be towed underwater to a small sheltered bay near the island of Kaprije, where it ran aground where 700 tons of vinyl chloride were recovered by pumping.

Date: 16/11/1984	**Risks associated:**
Place: Yugoslavia, Adriatic Sea	**Vinyl chloride monomer:**
Pollutant's type: vinyl chloride monomer,	**H220** - extremely flammable gas
Packaging: tanks	**H350** - can cause cancer
Quantity spilled: 1300 tons	
Cause of incident: structural damage	

Components' vapour pressure (25°C):

Vinyl chloride monomer: 397 kPa

REFERENCES

Fiche toxicologique INRS chlorure de vinyl

cedre.fr, 2009, Brigitta Montanari

Review of chemical spills at sea and lessons learnt, cedre, 2009

Loostrom.com, Brigitta Montanari

Photo, Cedre

2.3.7. ARIADNE

The grounding of the Panamanian container ship Ariadne took place on August 24, 1985 near the port of Mogadishu in Somalia. The ship's cargo consisted of 600 containers of which 10 contained various chemicals (acetone, butyl acetate, dipentene, ethyl acetate, hexane, hydrazine, isobutyl alcohol, isopropyl alcohol, methyl isobutyl ketone, methyl ethyl ketone, toluene, xylene, hydrogen peroxide, organochlorinated pesticides, Sodium pentachloro phenate, Tetraethyl lead, Trichlorethylene, Nitric acid). Despite a request for assistance from the Somali government, and the intervention of experts in the fight against the fire, the chemical spill and the environmental impact assessment, a fire occurred on the ship and a drive was carried out to evacuate a part of the harbour area. Following this fire, the authorities decided to refloat the ship. This intervention resulted in the rupture of the vessel and the dispersion of the cargo and bulk oil. 250 drums were dumped ashore and recovered, along with bunker oil and most of the cargo. However, some of the tetraethyl lead, sodium pentachloro phenate and trichlorethylene was never recovered. 4 months later the forward part of the wreckage was towed and sunk 35 nautical from the coast and the rest of the vessel was dismantled after nine months.

Date: 24/08/1985	**Risks associated:**
Place: Somalia	**Nitric acid:**
Pollutant's type: Acetone, Butyl acetate, Dipentene, Ethyl acetate, Hexane, Hydrazine, Isobutyl alcohol, Isopropyl alcohol, Methyl isobutyl ketone, Methyl ethyl ketone, Toluene, Xylene, Hydrogen peroxide, Organchlorine pesticides, Sodium pentachlorophenate, Tetra ethyl lead, Trichloroethylene, Nitric acid	**H272** - can worsen the fire **H314** - causes severe skin burns and severe eye lesions **Trichloroethylene:** **H350** - can cause cancer **H341** - can induce genetic disorders **H319** - causes severe eye irritation

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Packaging: tank containers	**H315** - causes skin irritation
Quantity spilled: not available	**H336** - can cause somnolence or dizziness H412 - harmful for aquatic organisms, causes harmful effects long term
Cause of incident: grounding due to broken towing equipment	
Components' vapour pressure (25°C):	**Toluene:**
Acrylonitrile: 14,5 kPa	**H225** - very flammable liquid and vapour
	H361d - can be harmful to foetus
REFERENCES	**H304** - can be deadly in case of ingestion and penetration into the respiratory tract H373 - presumed risk of severe effects following repeated exposure or an extended exposure
Helcom response manual, volume 2, 2002	
Pubchem	**H315** - causes skin irritation
	H336 - can cause somnolence or dizziness

2.3.8. ANNA BROERE

The collision between the Dutch chemical tanker Anna Broere and the Swedish container ship Atlantic Compass took place on May 27, 1988. On that day, the chemical tanker Anna Broere was carrying 547 tons of acrylonitrile and 500 tons of dodecylbenzene and was on its way to England from Rotterdam and sank in shallow water as a result of the collision. Acrylonitrile is a widely used chemical in the chemical plastics industry. It is both very dangerous for humans but also for the marine environment. It is also very explosive in the air when it is present in a proportion of between 3% (lower explosive threshold) and 17% (upper explosive threshold). This risk led to the establishment of an exclusion zone with a radius of 10 km and 300 m high. Despite the bad weather, recovery operations initiated by the Dutch authorities have recovered half of the acrylonitrile, the other half having dispersed in the marine environment.

Date: 27/05/1988	**Risks associated:**
Place: the Netherlands, open sea	**Acrylonitrile:**
Pollutant's type: acrylonitrile, dodecyl benzene	**H225** - very flammable liquid and vapour H301 - poisonous in case of ingestion
Packaging: tank containers	**H311** - poisonous by skin touch
Quantity spilled: not available	**H315** -causes skin irritation
Cause of incident: collision	**H317** - can cause allergies
Components' vapour pressure (25°C):	**H318** - causes severe eye lesions
Acrylonitrile: 14,5 kPa	**H331** - poisonous by inhalation

REFERENCES *Helcom response manual, volume 2, 2002* *Pubchem*	**H335** - can irritate the respiratory tract H350 - can cause cancer **H411** - poisonous for aquatic organisms, causes harmful effects long term

2.3.9. JULIE A

The dry freighter Julie A was moored in the port of Århus in Denmark when it reported to authorities a leak in a hydrochloric acid tank on November 4, 1989. This reservoir contained 300 tons of 33% hydrochloric acid. Hydrochloric acid is a strong acid that has reacted with the iron in the sheets of the ship to form hydrogen gas. Despite the intervention and the sealing of the leak by the emergency services, the acid managed to reach the ballast tanks and threatened to reach the bottom of the ship. In order to prevent the cargo from spilling into the environment the vessel was put in dry dock, the acid was pumped through a hole made in the hull of the vessel, but this did not prevent spillage between 1 to 5 tons of hydrochloric acid in the port of Århus.

The causes of the accident were linked to the improper coating of the fiberglass reinforced polyester tank which was corroded by hydrochloric acid. This incident highlights the need to know precisely the chemicals transported in order to have the right type of transport and response equipment as well as to correctly assess the consequences in terms of spills.

Date: 04/11/1989 **Place:** Denmark **Pollutant's type:** Hydrochloric acid **Packaging:** cylindrical tanks **Quantity spilled:** 1 to 5 tons **Cause of incident:** structural damage, tank's corrosion by hydrochloric acid **Components' vapour pressure (20°C):** **Hydrochloric acid:** 4220 kPa **REFERENCES** *Helcom response manual, volume 2, 2002* *Fiche toxicologique INRS acide chlorohydrique*	**Risks associated:** **Hydrochloric acid:** **H331** - harmful by inhalation **H314** - causes severe skin burns and eye lesions

2.3.10. OOSTZEE

On June 18, 1989, the Dutch cargo ship Oostzee, which was carrying 975 tons of epichlorohydrin in 3,900 drums of 250kg, encountered a storm while it was on the itinerary from Rotterdam to Leningrad. Despite the vertical stowage of the drums on the tween decks of the ship, some drums exhibited leaks which created a dangerous and toxic atmosphere (epichlorohydrin is used as a solvent for cellulose, resins and paints, and she found a use as a fumigant against insects) which led to the intoxication of part of the crew of the Oostzee. German maritime authorities then asked the ship to drop anchor in an area near Cuxhaven in northern Germany in order to hospitalize the 14 crew members for 10 days. The risk of explosion being significant and the toxicity of the products spilled inside the ship being high, the authorities decided to transfer the ship to a sparsely populated port in the Elbe estuary. As a first step, a large safety zone of 100 m in diameter was established around the ship and airspace was closed to a height of 600m. In order to reduce the risk of explosion the engine rooms have been ventilated with the aim of reducing the concentration of epichlorohydrin vapours to 3 ppm. Of the 3,900 drums transported, 263 drums were damaged, transferred to overpacks and then transported to a chemical company for disposal. Despite this, during the response, 8,100 L of epichlorohydrin was released into the atmospheric environment.

Date: 18/06/1989	**Risks associated:**
Place: German Bight	**Epichlorohydrin:**
Pollutant's type: epichlorohydrin	**H226** - flammable liquid and vapour
Packaging: drums	**H350** - can cause cancer
Quantity spilled: not available	**H331** - poisonous by inhalation
Cause of incident: shifting of cargo due to improper storage	**H311** - poisonous by skin touch
	H301 - poisonous in case of ingestion
Components' vapour pressure (25°C):	**H314** - causes severe skin burns and eye lesions
Epichlorohydrin: 2186 kPa	**H317** - can cause skin allergies

REFERENCES

Helcom response manual, volume 2, 2002

Fiche toxicologique INRS epichlorydrine

Loostrom.com, Oostzee

2.3.11. ALESANDRO PRIMO

The accident of the chemical tanker Alessandro Primo took place on February 1, 1991 off the coast of Italy in the Adriatic Sea. At the time of the accident, the vessel was carrying 550 tons of

acrylonitrile and 3,000 tons of ethylene dichloride and sank 16 nautical miles from the coast. In order to secure the accident area, maritime authorities established an exclusion zone of ten nautical miles radius around the vessel. Monitoring of the area made it possible to measure traces of acrylonitrile 500 m from the position of the wrecks four days after the sinking. In order to inspect the wreckage a ROV was used and detected an acrylonitrile leak. First, the leak was stoppered, then product recovery was undertaken to prevent major pollution in the area. Despite the speed of intervention and the many precautionary measures that were taken during this dangerous operation, a small part of the quantity present in the tanks of the Alesandro Primo was recovered, the rest having dispersed in the marine environment prior to the start of the recovery operation.

Date: 01/02/1991	**Risks associated:**
Place: Adriatic sea, north east of Molfetta, Italy Pollutant's type: acrylonitrile, ethylene dichloride	**Acrylonitrile:** **H225** - very flammable liquid and vapour H301 - poisonous in case of ingestion
Packaging: tank containers	**H311** - poisonous by skin touch
Quantity spilled: not available	**H315** -causes skin irritation
Cause of incident: not available	**H317** - can cause allergies
Components' vapour pressure (25°C):	**H318** - causes severe eye lesions
Ethylene dichloride: 10,5 kPa	**H331** - poisonous by inhalation
Acrylonitrile: 14,5 kPa	**H335** - can irritate the respiratory tract H350 - can cause cancer
REFERENCES	**H411** - poisonous for aquatic organisms, causes harmful effects long term
Helcom response manual, volume 2, 2002	**Ethylene dichloride:**
Pubchem	**H225** - very flammable liquid and vapour
	H350 - can cause cancer
	H301 - poisonous in case of ingestion
	H319 - causes severe eye irritation
	H335 - can irritate the respiratory tract H315 - causes skin irritation

2.3.12. GRAPE ONE

The accident of the chemical tanker Grape One took place on December 9, 1993 in the English Channel off the coast of Devon between the Tees and Haifa in bad weather conditions. At the time of the accident, the vessel was carrying 3,000 tons of xylene, a weak but highly flammable pollutant (xylene is used as a solvent, for cleaning, as a pesticide, as a thinner for paints, as well as in varnishes and inks). The accident was caused by the vessel's 40-degree list associated with a

ballast rupture that resulted in the sinking of the Grape One with all of its cargo. The crew were rescued by helicopter and sent to Plymouth Hospital. No other response was implemented after the sinking and the amount of cargo spilled into the marine environment is still unknown.

Date: 09/12/1993	**Risks associated:**
Place: Channel, Great Britain	**Xylene:**
Pollutant's type: xylene	**H226** - flammable liquid and vapour
Packaging: tanks	**H332** - poisonous by inhalation
Quantity spilled: 3000 tons	**H312** - poisonous by skin touch
Cause of incident: structural damage (error with ballasting ship caused shipwreck)	**H315** - causes skin irritation
Components' vapour pressure (31°C) :	
Xylène : 1,33 kPa	
REFERENCES	
Fiche toxicologique INRS xylene	
cedre.fr, 2009, Grape One	
Chemical spills at sea and lessons learnt, cedre, 2009	

2.3.13. N°1 CHUNG MU

The cargo ship Chon Stone No. 1 collided with the Chung Mu No. 1, a chemical tanker built in 1994 in the access channel to the port of Zhanjiang in southern China on March 9, 1995. At the time of the accident, the chemical tanker Chung Mu No. 1 was carrying 3,500 barrels loaded with styrene monomer and dumped 208 tons in the sea. The rapid intervention of the divers made it possible to plug the leak but it is probable that styrene has continued to escape. Styrene is an aromatic organic compound used to make plastics and in particular polystyrene. From a toxicity standpoint, styrene vapours are neurotoxic to humans and the product can be absorbed by fish and shellfish in the short term. The Chung Mu was immobilized by the authorities and ordered to provide a large bank guarantee due to the potential damage to aquatic species. The insurance club commissioned Cedre for two missions in China, in order to assess the damage that living resources had suffered. This estimate enabled the insurance club to agree with the authorities on a reasonable deposit and the release of the vessel.

Date: 09/03/1995	**Risks associated:**
Place: China	**Styrene:**
Pollutant's type: styrene monomer	**H226** - very flammable liquid and vapour
Packaging: steel cylinders	**H332** - harmful by inhalation
Quantity spilled: 208 tons	**H319** - causes severe eye irritation
Cause of incident: collision	**H315** - causes skin irritation
Components' vapour pressure (20°C):	**H361d** - can be harmful to foetus
Styrene: 0,7 kPa	**H372** - confirmed risks of harmful effects to organs

REFERENCES

Helcom response manual, volume 2, 2002

Fiche toxicologique INRS styrène

cedre.fr, 2009, N°1 Chung Mu

Photo, Cedre

2.3.14. MULTITANK ASCANIA

On March 19, 1999, the chemical tanker Multitank Ascania, carrying a cargo of 1,800 tons of vinyl acetate, reported a fire on board while sailing north of Scotland in the Pentland Firth. Vinyl acetate is a flammable and polymerizable liquid used in solution in various solvents, or as a component of raw materials for adhesives and as a finishing agent for the textile and paper industries. The fire started in the engine room following an oil leak from a thermal oil pump. Despite the crew intervening with fire extinguishers initially and then flooding the engine room with the CO2 extinguishing system, the fire could not be brought under control. The risk of explosion being very important, the rescuers decided to evacuate the crew except the captain who remained to anchor the ship (this one having been evacuated subsequently) and determined an exclusion zone of a radius of 5 km around the ship. The establishment of this danger zone required the evacuation of 600 residents. Following a camera examination of the vessel and temperature measurements taken by rescuers on the vessel, the maritime authorities decided to tow the Multitank Ascania Scapa Flow to Orkney Islands. As the vessel was severely damaged, its cargo had to be transferred to another vessel and the Multitank Ascania was then towed to the port of Rotterdam.

Date: 19/03/1999	**Risks associated:**
Place: Great Britain, open sea, North of Scotland	**Vinyl acetate :**
	H225 - very flammable liquid and vapour

Pollutant's type: vinyl acetate
Packaging: cargo tanks
Quantity spilled: unknown
Cause of incident: fire
Components' vapour pressure (20°C):
Vinyl acetate: 11,7 kPa

REFERENCES

Cedre.fr, 2009, Spills : multitank ascania

Fiche toxicologique INRS acétate de vinyl

photo : shipspotting.com

H332 - harmful by inhalation
H335 - can irritate the respiratory tract
H351 - can cause cancer

2.3.15. MARTINA

The accident of the Liberian chemical tanker Martina took place on March 28, 2000 in the Öresund Strait, between Denmark and Sweden. With poor visibility that day, the Martina, which was carrying a cargo of 600 tonnes of 30% hydrochloric acid, collided with the Maltese container ship Werder Bremen. In the collision, the chemical tanker Martina broke into two parts and the aft part of the vessel sank immediately and the rest of the vessel which contained the cargo sank after 2 hours. Despite the intervention of rescuers, only 2 of the 7 crew members were rescued. Regarding the vessel, the very bad weather conditions did not allow immediate action on the cargo. It was not until March 30 that the two parts of the ship were located and it was decided to release the hydrochloric acid into the environment under control and pump out the bunker oil.

Date: 28/03/2000
Place: Sweden, open sea
Pollutant's type: hydrochloric acid
Packaging:
Quantity spilled: 600 tons
Cause of incident: collision
Components' vapour pressure (20°C) :
Hydrochloric acid: 4220 kPa

REFERENCES

Risks associated:
Hydrochloric acid:
H331 - harmful by inhalation
H314 - causes severe skin burns and eye lesions

cedre.fr, 2000, Martina

Fiche toxicologique INRS acide chlorhydrique

photo : NauticExpo.com

2.3.16. IEVOLI SUN

The accident of the Ievoli Sun took place on October 30, 2000 off Cherbourg in France. Caught in a storm, the ship sailing from Fawley in the UK to Bar in Yugoslavia was carrying a total of 6,000 tons of chemicals (1,027 tons of Methyl Ethyl Ketone, 996 tons of IsoPropyl Alcohol, 3,998 tons of styrene) and carried 14 crew members on board. Following the warning signal from the captain of the Ievoli Sun for a leak in the forward section of the double bottom. The Atlantic maritime prefect in Brest then sent the tug Abeille Flandre, based on the Ushant Island, to assist the ship and a Super helicopter to assess the seriousness of the situation and evacuate the crew to a safer place. Following the rescue operation and the situation of the vessel, the Maritime Prefect activated the POLMAR Plan. As the meteorological and maritime conditions in the area at this point could lead to a risk of stranding and major pollution on the Côtes d'Armor coast, it was decided to tow the Ievoli Sun to the northeast of the accident area to the shelter of the Cotentin peninsula. On October 31, at 9:00 a.m., two-thirds of the way, the Ievoli Sun sank at a depth of 70 m, 9 nautical miles north of the Casquets rail. After analysing the condition of the wreck, it was decided that the most suitable solution would be to pump styrene and heavy fuel oil. Methyl ethyl ketone and isopropyl alcohol could be released under close surveillance, which was done in April-May 2001 by an assistance team contracted for this purpose. Water and air samples were taken from the area during operations, but tests did not show any evidence of styrene leakage. Operations were completed in May 2001.

Date: 31/10/2000	**Risks associated:**
Place: France, open sea	**Styrene:**
Pollutant's type: styrene, MEC (methyl ethyl ketone), isopropyl alcohol	**H226** - very flammable liquid and vapour
	H332 - harmful by inhalation
Packaging: bulk	**H319** - causes severe eye irritation
Quantity spilled: unknown	**H315** - causes skin irritation

Cause of incident: structural damage

Components' vapour pressure (20°C):

Styrene: 0,7 kPa

Isopropyl alcohol: 4,4 kPa

Evaporation indicator: 1,7

H361d - can be harmful to foetus

H372 - confirmed risks of harmful effects to organs

Isopropyl alcohol :

H225 - very flammable liquid and vapour

H319 - causes severe eye irritation

H336 - can cause dizziness or somnolence

REFERENCES

cedre.fr, 2000, Ievoli Sun

Fiche toxicologique INRS alcool isopropylique

Fiche toxicologique INRS styrène

photo : cedre

2.3.17. CASTOR

On December 26, 2000, when the weather conditions were deteriorating off the coast of Nador in northern Morocco, the Cypriot oil tanker Castor, which was carrying a cargo of 29,500 tons of unleaded gasoline, made its way from Romania to Nigeria. The weather being very unfavorable, the ship presented a crack of 24 m on the main deck of the ship on the night of December 30, 2000. The authorities decided to evacuate the crew because of the risk of explosion generated by the vapours of gasoline. A response team then intervened quickly to make emergency repairs and strengthen the structure of the ship. Following the repairs, the ship was towed but several ports refused to accommodate the tanker and it was not until February 8, 2001, after 40 days of navigation in the Mediterranean, that the cargo was transferred off the Tunisian coast. Post-accident analysis showed that the Castor's corrosion rate was fifteen times higher than expected.

Date: 31/12/2000

Place: Morocco

Pollutant's type: gasoline

Packaging:

Quantity spilled: 29 500 tons

Cause of incident: damage

Components' vapour pressure (25°C):

Benzene: 12,6 kPa

Risks associated: Gasoline vapours have benzene

Benzene:

H225 - very flammable liquid and vapour

H350 - can cause cancer

H340 - can cause genetic disorders

H372 - confirmed risks of harmful effects for organs following repeated exposure or extended exposure

REFERENCES *cedre.fr, 2000, CASTOR* *Fiche toxicologique INRS Benzene*	**H304** - can be deadly in case of ingestion and penetration into the respiratory tract **H319** - causes severe eye irritation **H315** - causes skin irritation

2.3.18. JESSICA

The Jessica tanker accident occurred on January 16, 2001 in the Port Baquerizo Moreno inlet the channel at Wreck Bay on San Cristobal Island, Galapagos. The weather conditions associated with the storm led to the grounding of the vessel, which was carrying 600 tonnes of diesel and 300 tonnes of IFO 120 (Intermediate Fuel Oil). The IFO spill began on Saturday January 20, 2001 and immediately GNP, Navy personnel, fishermen and local volunteers began to contain and recover the oil on the surface of Wreck Bay. All the dispersant available at the time was used around the "Jessica", and the oiled animals (sea lions, pelicans, boobies) were treated. Due to the lack of essential equipment and especially due to the sea conditions and the degree of heeling of the boat, the staff were unable to control the contamination. The slicks began to drift with the prevailing wind and ocean currents towards Cerro Tijeretas and Isla Lobos (San Cristobal Island) and Santa Fé Island, 20 miles west-northwest of San Cristobal. In the afternoon of Sunday 20, the US Coast Guard arrived in San Cristobal with specialized equipment. The barge "Cirius" also arrived from Guayaquil with dispersant and absorbent materials. On Monday 22nd, the US Coast Guard began operations to remove the remaining fuel from the boat. At the end of the US Coast Guard recovery operations (01/31/01), it was estimated that less than 3,785 liters of fuel oil remained on board in the service tanks. The quantity of fuel oil spilled was estimated at approximately 250 tons of diesel and IFO. Very shortly after the start of the leak, in the afternoon of Sunday 20, overflights of the area showed that slicks were dispersed over a large area (approximately 1,000 km^2). Slicks were also observed drifting over the following days between the islands under the influence of the prevailing wind and currents.

Date: 16/01/2001 **Place:** Ecuador, inshore **Pollutant's type:** light fuel oil and intermediate fuel oil **Packaging:** **Quantity spilled:** 600 tons **Cause of incident:** grounding	**Risks associated:** **Fuel oil:** **H224** - very flammable liquid and vapour **H304** - can be deadly in case of ingestion and penetration into the respiratory tract **H319** - causes severe eye irritation **H336** - can cause dizziness or somnolence **H350** - can cause cancer

REFERENCES *cedre.fr, 2000, Jessica*	**H373** - confirmed risks of harmful effects on organs following repeted exposure or extended exposure **H411** - harmful for aquatic organisms, causes harmful effects long term Vapours can make an explosive mixture with air.

2.3.19. BOW EAGLE

On August 26, 2002, the trawler Cistude collided with the Norwegian chemical vessel Bow Eagle. The trawler was transiting off the island of Sein and the chemical tanker, which was coming from ports on the east coast of South America and bound for Rotterdam, was on its way to the entrance to the Outer Uplink of Ushant. At the time of the incident, the shock was violent, the bow of the trawler struck the port bow of the chemical tanker at the level of the bow bulb. The chemical tanker nevertheless continued on his way and did not report the collision. The severely damaged trawler hung on the bulbous bow of the Bow eagle for a few moments, then slid along the port side of the chemical tanker which it struck several times. The trawler capsized and her crew was thrown overboard and the trawler sank in about 15 minutes. The chemical tanker also sustained damage, which was not noticed until the following afternoon, with severe scratches and dents on her port side. Two of her side cargo tanks on the port side were punctured, with product leaking overboard. The collision resulted in the deaths of 4 people in Cistude and the spill of 200 tons of ethyl acetate from Bow Eagle. The vessel was carrying many substances, including soy lecithin, sunflower oil, methyl ethyl ketone, cyclohexane, toluene, ethyl acetate, benzene and ethanol. This was a high risk given the cocktail of chemicals on board the ship

Date: 26/08/2002	**Risks associated:**
Place: France, open sea	**Ethyl acetate:**
Pollutant's type: ethyl acetate, cyclohexane	**H225** - very flammable liquid and vapour
Packaging: bulk	**H319** - causes severe eye irritation
Quantity spilled: 200 tons of ethyl acetate	**H336** - can cause dizziness or somnolence
Cause of incident: collision	**EUH 066** - repeted exposure can cause skin dryness or skin chapping
Components' vapour pressure (20°C) :	It is a very flammable liquid and, in some conditions, its vapours can cause explosive mixtures, water being able to boost the propagation of an already declared fire.
Ethyl acetate: 10 kPa	
Cyclohexane: 12,7 kPa	
REFERENCES *Cedre.fr, 2000, Bow Eagle*	**Cyclohexane:**

Fiche toxicologique INRS cyclohexane *Fiche toxicologique INRS ethyl acetate* *Regulatory SAR issues related to maritime autonomous surface ships (MASS), 2018* *Review of chemical spills at sea and lessons learnt,*	**H225** - very flammable liquid and vapour **H319** - causes severe eye irritation **H336** - can cause dizziness or somnolence **H315** - can cause skin irritation **H410** - very toxic for aquatic organisms, causes harmful effects long term

2.3.20. SPABUNKER IV

The accident of the oil barge Spabunker IV took place on January 21, 2003 in the bay of Algeciras in Spain. The unfavorable weather conditions, with heavy swells and high winds caused a waterway in the stern of the barge and caused a leak which caused the sinking of the barge in the bay at 50 m depth. During the sinking, the barge was carrying 1,000 tons of fuel oil (900 tons of light fuel oil and 100 tons of diesel). Despite the leak, only a small amount of the product was released into the environment and the resulting pollution was quickly brought under control. In the accident, two crew members were rescued from the sea but the captain was missing.

Date: 21/01/2003 **Place:** Spain **Pollutant's type:** light fuel oil and gasoline **Packaging:** bulk **Quantity spilled:** 900 tons of light fuel oil and 100 tons of gasoline **Cause of incident:** bad weather conditions **REFERENCES** *cedre.fr, 2000, Spabunker IV*	**Risks associated:** **Fuel oil:** **H224** - very flammable liquid and vapour **H304** - can be deadly in case of ingestion and penetration into the respiratory tract **H319** - causes severe eye irritation **H336** - can cause dizziness or somnolence **H350** - can cause cancer **H373** - confirmed risks of harmful effects on organs following repeted exposure or extended exposure **H411** - harmful for aquatic organisms, causes harmful effects long term Vapours can make an explosive mixture with air.

2.3.21. BOW MARINER

The Bow Mariner accident took place on February 28, 2004, 57.5 miles off the Chincoteague Channel, Virginia, United States, while carrying 11,000 tons of ethanol from New York to Houston. A large explosion occurred after a fire broke out on the deck of the ship, the ship then sank an hour

and a half later in international waters at a depth of 80 m. In the accident, three people were killed and 18 others were missing. Ethanol is very soluble in water and slightly toxic. It has a low flash point and is classified Marpol category 3 with low environmental impact.

The intervention of the NOAA ship Rude made it possible to locate the wreckage and determine its position on the seabed using sonar images. The American authorities sent the Virginia Responder, an MSRC (Marine Spill Response Corporation) intervention vessel, which was able to recover 7 tons of oil. Environmental impact studies have shown that the pollution linked to the spill of 1,000 tons of ethanol, 720 tons of heavy fuel oil (IFO 380) and 166 tons of marine diesel had a very low impact on flora and fauna.

Date: 28/02/2004

Place: off the coast of Virginia, open sea

Pollutant's type: ethanol, heavy fuel oil, marine diesel oil

Packaging: bulk

Quantity spilled: 1,000 tons of ethanol, 720 tons of heavy fuel oil (IFO 380) and 166 tons of marine diesel oil

Cause of incident : explosion

Components' vapour pressure (20°C) :

Ethanol : 5,9 kPa

Evaporation indicator : 8,3 (diethyl ether = 1)

REFERENCES

Cedre.fr, 2004, Bow Mariner

Fiche toxicologique INRS ethanol

Photo

Risks associated:

Ethanol:

H225 - Liquide et vapeurs très inflammable

2.3.22. SAMHO BROTHERS

The accident with the chemical vessel Samho Brother occurred on October 10, 2005 in the Taiwan Strait on the way from Pusan, South Korea to Taichung, Taiwan. The collision with the TS Hong Kong container ship occurred northwest of Hsinchu, Taiwan as the Samho Brother was carrying a cargo of 3,136 tons of benzene, 65 tons of intermediate fuel (IFO-180) and 16 tons of marine diesel (MDO) as bunker fuel. Following the collision, the fourteen crew members were rescued by the Taiwan Coast Guard. The Taiwanese government immediately set up a Hazard Response Center (HRC).

Vessels were sent to areas near the site to take air and seawater samples for analysis. The owner's proposal was to burn the benzene, and the HRC agreed that this was doable. The combustion temperature of benzene is low, and only 0.07% dissolves in water, so it was expected to be burned quickly after an explosion. On October 27, attempts were made to ignite benzene with missile fire. However, the ship was damaged only in the bow and there was no explosion. The oil began to leak immediately and then the Samho Brother sank, stern first, in 70 m of water with the bow above the surface. The oil spill was recovered in small quantities, leaving around 50 tons of fuel in the ship's tanks. In addition, environmental monitoring at the accident site revealed that almost all of the large quantity of 3,140 m^3 of benzene remains stored in the ship's nine tanks.

Date: 10/10/2005

Place: Taiwan, China

Pollutant's type: benzene, intermediate fuel oil, marine diesel

Packaging: bulk

Quantity spilled: 3,136 tons of benzene, 65 tons of intermediate fuel oil (IFO-180) and 16 tons of marine diesel (MDO)

Cause of incident: collision

Components' vapour pressure (25°C):

Benzene: 12,6 kPa

Evaporation indicator: 3 (diethyl ether = 1)

REFERENCES

ITOPF, 2005, Samho Brothers

Fiche toxicologique INRS benzène

Naphta léger (pétrole) - Carl Roth

Risks associated:

Benzene:

H225 - very flammable liquid and vapour

H350 - can cause cancer

H340 - can cause genetic disorders

H372 - confirmed risks of harmful effects for organs following repeated exposure or extended exposure

H304 - can be deadly in case of ingestion and penetration into the respiratory tract

H319 - causes severe eye irritation

H315 - causes skin irritation

2.3.23. MONTARA

On August 21, 2009, the Montara drilling platform owned by PTTEP Australasia suffered a wellhead accident resulting in an uncontrolled release of oil and gas. The incident occurred about 230 km off the northwest coast of Australia in the Montara offshore oil field in the Timor Sea. Despite the risk

of explosion linked to the gas release, the intervention on the well head stopped the leak on November 3, 2009. The Australian Maritime Safety Authority coordinated the emergency response in the event of a spill, in accordance with the Australian National Plan to Combat Pollution of the Sea by Oil and Other Noxious and Hazardous Substances. Rescuers intervened to safely evacuate the 69 engineers and technicians from the platform to the city of Darwin in northern Australia.

Date: 21/08/2009

Place: Australia, Timor sea, open sea

Pollutant's type: light crude oil, condensates and gas

Packaging:

Quantity spilled: 4800 tons

Cause of incident: oil eruption on a platform

REFERENCES

cedre.fr, 2009, Montara

Photo AMSA

Risks associated:

Fuel oil:

H224 - very flammable liquid and vapour

H304 - can be deadly in case of ingestion and penetration into the respiratory tract

H319 - causes severe eye irritation

H336 - can cause dizziness or somnolence

H350 - can cause cancer

H373 - confirmed risks of harmful effects on organs following repeated exposure or extended exposure

H411 - harmful for aquatic organisms, causes harmful effects long term

Vapours can make an explosive mixture with air.

2.3.24. STOLT VALOR

On March 15, 2012, the Liberian chemical tanker Stolt Valor which was carrying 12,700 tons of additive to gasoline (methyl tertiary-butyl ether (MTBE), isobutyl aldehyde (IBAL), Intermediate Fuel Oil (IFO 380)), highly flammable product was the victim of an explosion followed by a fire that lasted 5 days. The 24 Filipino crew were picked up by a nearby US warship (a sailor is missing). The incident took place off the port of Jubail (Saudi Arabia) where he had loaded his cargo. On March 18,

the drifting tanker reached Qatar's exclusive economic zone, where it was the victim of a second explosion. On March 20, the company SMIT Salvage, after having brought the fire under control, succeeded in passing a trailer and pulling it away from the coast. The vessel was cleared to anchor in the middle of the ROPME maritime area to undertake rescue operations. On April 29, after the cargo of chemicals and other pollutants had been transferred to the tanker Angel-11, the shipowner applied to the Kingdom of Bahrain for permission to repair the ship at ASRY shipyards in Bahrain. Investigations following the accident determined that 3,465 tons of MTBE were reportedly dumped into the sea.

Date: 16/03/2012

Place: Saudi Arabia, open sea

Pollutant's type: methyl tertiary-butyl ether (MTBE), isobutyl aldehyde (IBAL), Intermediate Fuel Oil (IFO 380)

Packaging: tank

Quantity spilled: unknown

Cause of incident: explosion, fire

Components' vapour pressure (20°C):

MTBE: 27 kPa

IBAL: 189 hPa

REFERENCES

cedre.fr, 2012, Stolt Valor

ITOPF, STOLT VALOR, off the Kingdom of Saudi Arabia, 2012

Fiche toxicologique INRS MTBE

Fiche toxicologique INRS IBAL

Photo : ITOPF

Risks associated:

MTBE:

H225 - very flammable liquid and vapour

H315 - causes skin irritation

IBAL :

H225 - very flammable liquid and vapour

H319 - causes severe eye irritation

2.3.25. ELGIN

On March 25, 2012, a gas leak was detected on the well head of the Elgin offshore oil and gas platform located in the North Sea, 240 km east of Aberdeen in Scotland. This leak caused a blowout (sudden and accidental expulsion of gas and mud) which caused the dispersion of a cloud of gas in the atmosphere. According to the oil group Total, the leak occurred at the head of a disused well (known as the "G4" well) which had been isolated for a year. The chalk formation, still unexploited, began to unexpectedly release gas, about 1000 meters above the exploited reservoir. Then the G4

well tube ruptured, possibly due to corrosion, at a pressure 30% lower than it would normally withstand.

The leak of oil and natural gas condensates (around 200,000 m^3/day) consisted of methane mainly for its gas phase but also of propane, butane and condensate aerosols which generated a cloud visible more than 10 km away. A thin oil slick formed over about 12 km^2, with a "relatively negligible environmental impact" according to the oil group. On March 29, 2012, aerial surveillance reported the presence of a 22 km x 4.5 km slick. According to Total, this spill could be corresponding to a volume of condensate on the water of 3.8 tons. The incident is then considered "very worrying" by the government, which added, however, that the response of Total and government agencies has been very effective. Everyone was safely evacuated from the platform and Total was looking for solutions to stop the release of gas as quickly as possible. According to the UK Department of Energy and Climate Change (DECC) there was no longer at this stage a substantial risk to the environment".

On May 3, the DECC and the Health and Safety Executive granted Total the environmental permits to undertake the sludge and chemicals injection operation and discharges necessary for operations aimed at stopping the gas leak. The pumping and injection of "heavy mud" began on May 15, 2012 and made it possible to stop the leak 12 hours later.

Date: 25/03/2012	**Risks associated:**
Place: Great Britain, open sea	**Gasoline vapours have benzene in them**
Pollutant's type: Methane and condensate comparable to gasoline	**Methane:** Very flammable and gas can make an explosive mixture with air.
Packaging: platform	
Quantity spilled: 12 000 000 m^3	**Benzene:**
Cause of incident: leak on an oil rig	**H225** - very flammable liquid and vapour
	H350 - can cause cancer
REFERENCES	**H340** - can cause genetic disorders
cedre.fr, 2012, Elgin	**H372** - confirmed risks of harmful effects for organs following repeated exposure or extended exposure
Fiche toxicologique INRS Benzene	
Picture : Ocean Energy Ressources	**H304** - can be deadly in case of ingestion and penetration into the respiratory tract
	H319 - causes severe eye irritation
	H315 - causes skin irritation

2.4. SYNTHESIS

The analysis of accidentology over the last 40 years clearly shows that the majority of accidents that released volatile, flammable or explosive products took place in Europe (Figure 2). Of the 25 incidents selected, some did not present major hazards and the solutions chosen to deal with the dispersion were to let the chemicals disperse into the sea. Moreover, some measures are often taken to decrease or eliminate human risks such as distance boats from the coastline, evacuate the crew and people at risk (Elgin, Montara). Another initiative is to put in place an exclusion zone, as for Alesandro Primo and Anna Broere where a 10 km exclusion zone was imposed for safety. Finally, it is also possible to recover dangerous substances, either by pumping directly chemicals on the boat or trying to recover them once already spilled into the ocean. The response also often involves intensifying fires and stopping leaks. In these cases, the substances did not have a significant impact on the marine environment and the population or crew was not endangered or had already been evacuated. However, the main hazards identified during these spill incidents were related to the formation of a potentially flammable or explosive vapour cloud. Regarding the impact on human health, most of the substances spilled have consequences such as skin and eye irritation or can damage the respiratory tract.

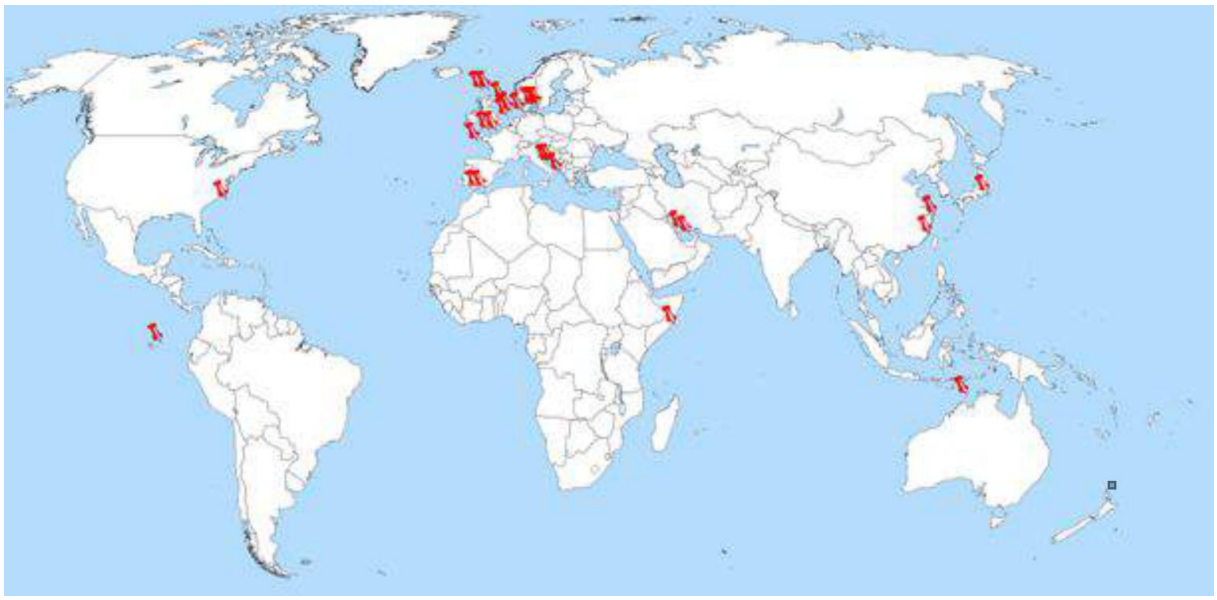

Figure 2: Location of the 25 maritime accidents involving evaporating, flammable or explosive products from 1974 to 2021.

It should be noted that all the behaviours described in the procedure for assessing the hazards of chemical substances transported by ships defined by GESAMP on behalf of the International Maritime Organization (IMO) are represented by the Standard European Behaviour Classification (SEBC). The SEBC classification helps to predict a pollutant's behaviour moments after the spill

thanks to its vapour pressure and solubility in water (Figure 3). For instance, a component with a vapour pressure between 0.3 and 3 kPa is going to float and evaporate. This component will form an evaporating pool at the sea surface. This type of substance is the one that interest us the most since it is likely to evaporate and form a vapour cloud.

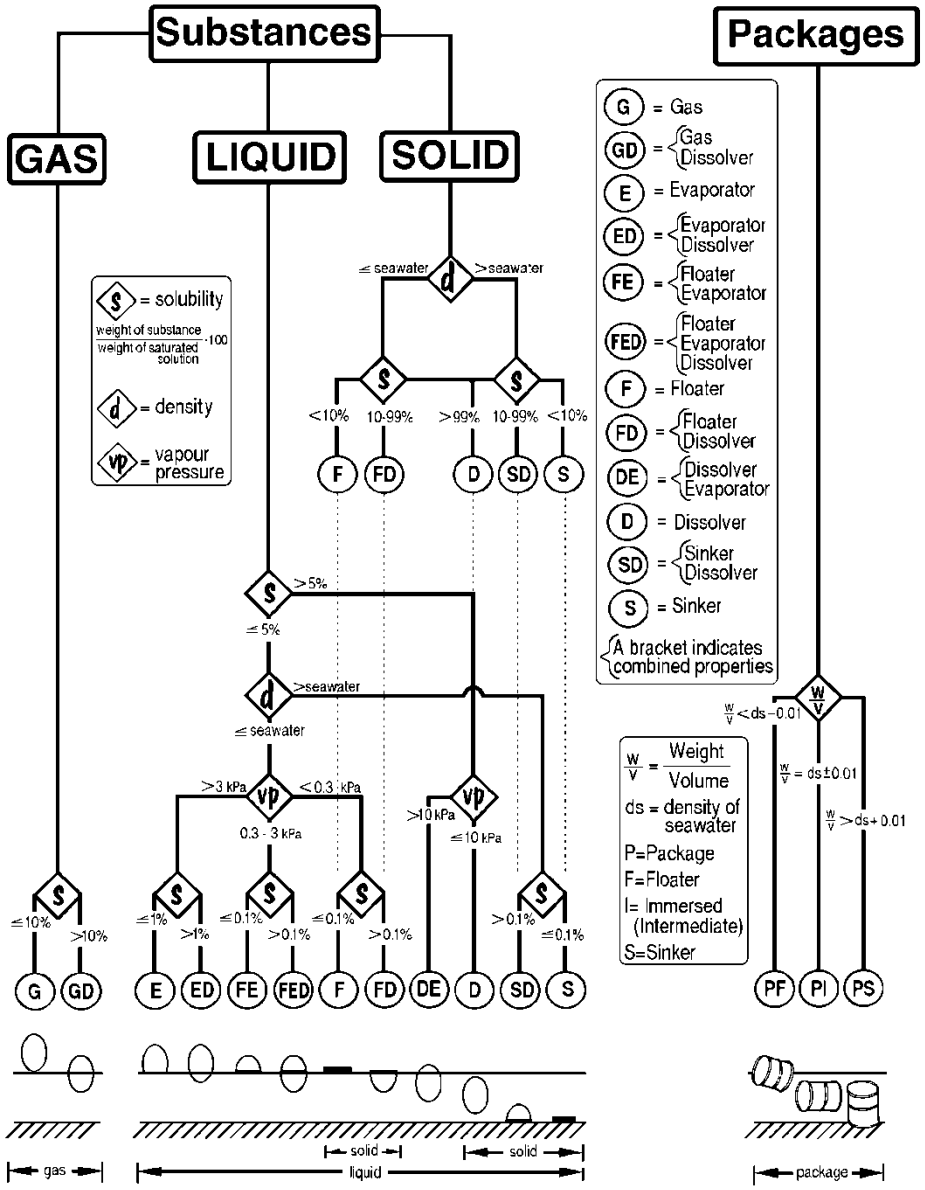

Figure 3: SEBC European Behaviour Classification groups. Classification of behaviour groups of chemical substances in the marine environment. Short-term behaviours are classified according to the physico-chemical properties of the substance: physical state, solubility, density and vapour pressure

Table 4 summarises the maritimes accidents involving volatile chemicals since 1974.

#	Date	Name	Transported Chemicals	Accident location	Quantity spilled
1	1974	Yuyo Maru	Propane, butane, Naphtha	Japan	Propane: 202 t Butane: 6 443 t naphtha: 20 831 t
2	1974	Cavtat	Tetraethyl lead and tetramethyl lead	Italy	270 t (total)
3	1976	René 16	Ammonia	Sweden	180 t
4	1976	Sindbad	Chlorine	Sweden	51 t
5	1980	Finneagle	Trimethyl phosphite	Orkney Islands	Not available
6	1984	Brigitta Montenari	Vinyl chloride Monomer	Yugoslavia	1 300 t
7	1985	Ariadne	Acetone, ethyl acetate, toluene, xylene ...	Somalia	Not available
8	1988	Anna Broere	Acrylonitrile, dodecyl benzene	The Netherlands	Not available
9	1989	Julie A	Hydrochlori acid	Denmark	1 to 5 t
10	1989	Oostzee	Epichlorohydrin	German Bight	Not available
11	1991	Alessandro Primo	Acrylonitrile, ethylene dichloride	Italy	Not available
12	1993	Grape One	Xylene	Great Britain	3 000 t
13	1995	N°1 Chung Mu	Styrene monomer	China	208 t
14	1999	Multitank Ascania	Vinyl acetate	Great Britain	Not available
15	2000	Martina	Hydrochloric acid	Sweden	600 t
16	2000	Ievoli Sun	Styrene, methyl ethyl ketone, isopropyl alcohol	France	Not available
17	2000	Castor	Gasoline	Morocco	29 500 t

18	2001	Jessica	Light fuel oil and intermediate fuel oil	Ecuador	600 t (total)
19	2002	Bow Eagle	ethyl acetate, cyclohexane	France	ethyl acetate : 200 t
20	2003	Spabunker IV	light fuel oil and gasoline	Spain	light fuel oil : 900 t gasoline : 100 t
21	2004	Bow Mariner	ethanol, heavy fuel oil, marine diesel	Virginia	ethanol : 1 000 t IFO 380 : 720 t Marine Diesel Oil : 166 t
22	2005	Samho Brothers	Benzene, intermediate fuel oil, marine diesel	Taiwan	Benzene :3 136 t IFO 180 : 65 t Marine Diesel : 16 t
23	2009	Montara	light crude oil, condensate and gas	Australia	4800 t (total)
24	2012	Stolt Valor	MTBE, IBAL, intermediate fuel oil	Saoudi Arabia	Not available
25	2012	Elgin	Gas and condensate	Great Britain	Not available

Table 4: recap chart maritime incidents.

2.5. References

[1] Cedre Spill Guide.http://www.cedre.fr/en/spill/chronological-classification.php

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