Fears and facts regarding Human health and safety hazards in oil and HNS spills

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1. INTRODUCTION

There have been some dramatic losses of human lives due to fire and explosion of tankers. There have been many reports of headache, skin irritation and other temporary and reversible impacts of oil on spill responders' health. There has been also considerable speculation about potential long term carcinogenic effects of exposure to oil since the Exxon Valdez incident. That last matter culminated in the Erika incident, where volunteers left in mass the beaches after a private laboratory dramatically pretended that the authorities had voluntarily hidden that they were exposed to a highly carcinogenic product. Public hearings in parliament were needed to calm down the major fears. There were finally more bruises and cuts than cancers among coastline responders. But the question of up to what point different oils and oil products are carcinogenic in spill response conditions remained open.

On another hand, it is commonly accepted that a number of chemicals are highly dangerous for human health and safety. And there are undeniable facts to support that acceptance. As an example, when the Maritime prefect decided to enter in the port of Brest, France, a cargo vessel loaded with ammonium nitrate wet from inflow through a hull crack, he had to face fierce opposition of the local authorities. They hadn't forgotten that the explosion, in the bay of Brest, of a liberty ship loaded with the same product, 5 decades earlier, had cause several deaths and hundreds of house destructions. When wheat spilled in Corsica, rotting in water, generated hydrogen sulphide, producing sulphuric acid, or when styrene seeped from a ship sunk in the Channel, the response authorities couldn't but consider the known neurotoxicity of those chemicals and equip their personnel accordingly.

This presentation will comparatively review the known fears and facts regarding immediate to long term human health and safety hazards related with oil, oil products, and those chemicals on which *Cedre* has produced a response guide.

2. RISKS RELATED WITH FIRE AND/OR EXPLOSION

2.1. Oil spills

There are not many examples of human lives taken by oil tankers bursting into flames and even less by oil tankers exploding. 4 such incidents are shortly described in table 1. The most dramatic, with a toll of 142 lives, was caused by a ferry boat, the Moby Prince, colliding with a laden tanker at anchor, the Agip Abruzzo, in front of the Italian port of Livorno, on 10 May 1991. In the other 3 incidents, human lives taken ranged from 5 to 50, either exclusively or mostly crew members.

Explosion of the oil tanker Betelgeuse, Bantry Bay, Ireland, June 1979: 50 people, including the 32 crew members, were killed by an explosion while loading at terminal. A further fatality occurred during the salvage operation, with the loss of a diver.
Fire and explosion of the tanker Vitoria, Seine river, 23 June 1987: collided by the Japanese tanker Fuyoh Maru, with a damaged helm, upstream of Tancarville bridge, the empty but not degassed Greek tanker Vitoria caught fire and exploded. The commanding officer, the pilot and 4 members of Victoria's crew were killed.
Ferry Boat colliding with the laden tanker Agip Abruzzo, Livorno, 10 April 1991: at 10.23 pm, the Ferry boat Moby prince collided with the oil tanker, at anchor in front of Livorno harbour. The ferry was engulfed in fire. 142 of the 143 passengers and crew onboard died a large portion of them intoxicated by massive toxic inhalation, while gathered in the main internal room of the ship.
Fire and explosion of the laden tanker Haven, Genoa, 11 April 1991: the ship was at anchor in the waiting area outside the port, with 140 000 tonnes of crude oil on board, when a fire broke out. It generated a succession of explosions. 5 of the 36 crew members, including the master, were killed. The ship sank in 3 parts, generating the largest accidental oil spill ever in the Mediterranean.

Table 1: Human casualties in fire and/or explosion of oil tankers

2.2. HNS incidents

There are not many examples of human lives taken by ships fire and/or explosion onboard ships transporting HNS. Five such incidents are summarily described in table 2. oil tankers bursting into flames and even less by oil tankers exploding. Five such incidents are shortly described in table 1. Two incidents took less than a handful of crewmember lives: a spill of caustic soda and alkyl benzene in California and spill of sodium chlorate and rapeseed oil in Sweden. Two incidents took respectively 23 and 26 lives. One, a stranded cargo vessel in Galicia, with a vast diversity of chemicals onboard, obliged to evacuate 15000 coastal inhabitants overnight. The other, the explosion of a cargo of ammonium nitrate in the bay of Brest, dramatically damaged the port facilities and at least 4000 houses in the surrounding town. The last incident, another explosion of ammonium nitrate the same year, in Texas City harbour, holds by far the world record of affected human lives, with some 600 killed and 3000 injured.

Fire and explosion of the cargo vessel Grandcamp, Texas city, USA, 16 April 1947: the liberty ship was loading a cargo of fertilizers, including ammonium nitrate, when fire burst out. It was being towed away from the loading pier when it exploded. Fire and explosions continued for 6 days. Most port equipment and facilities, many houses and buildings, were destroyed. 600 people died, 3000 were wounded.
Fire and explosion of the cargo vessel Ocean Liberty, bay of Brest, France. 1947; after the liberty ship *Ocean Liberty,* loaded with 3158 tons of ammonium, had entered safely in the Brest harbour, smoke was seen pouring from one of the closed holds, and a fire extended quickly. The ship was towed out in the bay of Brest, but it grounded on a sandbank. A huge explosion occurred. It killed 26 persons, among which all onboard, wounded hundreds and blasted port facilities and 4000 to 5000 houses and buildings downtown.
Fire in hold of the cargo vessel Poona, Gothenburg harbour, Sweden, 1971: The Poona had 36 tonnes of sodium chlorate and 600 tons of rapeseed oil stowed on pallets in the same hold when a steel structure being hoisted by a crane fell, creating sparks that ignited the mixture. The sodium chlorate was decomposed by the

heat to free oxygen, flames flared up out of the hold and three severe explosions occurred in rapid succession. Fire fighting was very dangerous due to the ferocity of the fire and also due to the fact that the ship also contained carbides. The final extinction of the fire took 10 days. Three persons were killed and six injured.
Explosion of chemical tanker Puerto Rican, San Francisco, California, USA; 1984: the ship was preparing to disembark the pilot when an explosion occurred in the vicinity of the vessel's centre void space number. 6. The main deck over the void and adjacent wing tanks was blown forward. The pilot, a third mate and a sailor were thrown over the side. The first 2 were recovered but not the sailor. The remaining 26 onboard abandoned the ship safely. 400-500 m3 of caustic soda solution and approximately 200 m3 of alkyl benzene leaked. a flammable mixture. An intense fire burned out of control for several hours. Days later, the vessel broke in two in heavy seas, and the stern section sank.
Fire and explosion of the Panamanian vessel Casón, Galicia, 5 December 1987: the cargo vessel Casón, carrying 1100 tonnes of chemicals, including toxic and strongly reactive flammable substances, in 5000 packages, got stranded in a storm and caught fire. 23 of her 31 crew died. After an explosion on December 10, during unloading, 15000 coastal inhabitants were evacuated overnight in 300 buses. The ship was carrying 126 tonnes of Sodium a metal corrosive to skin and eye, floating and violently reacting with water, with production of highly flammable hydrogen. That presence made it impossible to carry out efficient response before all the sodium had disappeared through reaction with water, on 12 March 1988.

Table 2: Fire and/or explosion of HNS with human casualties

Ten incidents that could have caused human casualty but didn't, either by pure chance or thanks to drastic response measures, are shortly described in table 3. They show a sample of the diversity of possible incidents, with:

- spills of liquefied gases, peroxydes, caustic soda, trimethyl phosphite, calcium carbide, sodium chlorate, palm oil
- oxidation of a cargo of deoxidized iron balls and damage to a cargo of ammonium nitrate
- losses and/or damages to containers and packages with acetone, butyl acetate, tetraethyl lead, toluene, trichloroethylene and xylene

Fire onboard the gas tanker Yuyo Maru n°10, , Tokyo bay, Japan, 1974: in fire after a collision, with a cargo of propane, butane and naphta, the ship was towed away and anchored out at sea.
Sodium peroxide spill while loading the Burgenstein, Bremerhaven, Germany, 1977: sodium peroxide drums were damaged by a fork-lift truck; spilled peroxide reacted with wet plastic sheets under a spinning truck wheel, fire spread to other spills of peroxide on deck and thereafter to the cargo, followed by a violent blaze. Fire fighting had to be carried out under great precaution due to the presence of cyanides in the cargo that could emit toxic hydrogen cyanide. Explosions forced the fire fighters to withdraw temporarily. The port and a large area around were declared as a safety zone and people in a part of the city were confined at home with doors and windows closed until the fire was extinguished. No human casualties were reported
Leaking of tank container in Swedish ro-ro Finneagle, North Sea, 1980: on a voyage from New Orleans to Valhamn (Sweden), in very hard weather, a tank container with trimethyl phosphite was damaged and started to leak. A fire broke out, soon followed by an explosion. Trimethyl phosphate, a flammable liquid with high flash point; reacts violently with acids with formation of dangerous phosphorous pentoxide gases. When in fire, foam or powder is recommended, water is not suitable. However, the sprinkler system sprayed about 300 tons of water until it stopped, after one hour, due to a pressure failure. Wearing breathing apparatus, the crew fought the fire in the smoked-filled ship, until they had to abandon it and where rescued by a British Search and Rescue helicopter. No casualties were reported
Risk of fire aboard the Stanislaw Dubois, 1981- North Sea: that Polish general cargo ship carried 857 tonnes of calcium carbide, 955 tons of caustic soda (solid sodium hydroxide), 5.4 tons of a flammable organic peroxide (generating the highly flammable gas acetylene on contact with water or moisture) and 5.6 tons of explosives, when she collided on her way in the North Sea with the Sudanese ship Omdurman off the Dutch island of Texel. The holds were flooded through a hole in the port side, created by the collision, causing the draught to increase to such an extent that it was impossible to enter any port for repair. After 7 days of negotiation, the Dutch authorities ordered the ship to be sunk in the NW of the island of Texel, at a depth of 72 m.
Grounding and fire of the containership Ariadne, Mogadishu, Somalia, 1985: while sailing out of the port, with a cargo of a cargo of 118 containers of hazardous chemicals, including acetone, butyl acetate, tetraethyl lead, toluene, trichloroethylene and xylene, the ship grounded on rocks some 100 metres from the shore. Salvage attempts failed, the ship listed more and more, part of the deck collapsed and a fire started

above one of the decks. Faced with toxic fumes drifting towards the city, authorities evacuated a number of inhabitants and companies in the port area. The vessel broke in two and large quantities of oil and cargo, including drums of chemicals, were washed ashore. No human casualties were reported
Fire onboard the gas carrier Val Rosandra, port of Brindisi, Italy, 1990: On the night of April 28, the Val Rosandra was discharging a cargo of liquefied propylene in the port of Brindisi when a fire started between the compressor room and the No 3 cargo tank. Liquefied (= compressed) propylene is flammable. It ignited. Fire crews doused the vessel with water from a safety distance of 300 m. After 3 weeks, the still burning vessel was towed 50 km off the coast, a safety zone was set up around it, and the four intact cargo tanks were ruptured with explosives to allow the remaining 1800 tonnes of propylene and the bunker fuel to burn off. A final round of explosives was used later to sink the ship.
Fire in the machine room of the ferry Korsnäs Link, the English coast, Teeside, UK, 1991: The Swedish ro-ro ferry Stora Korsnäs Link was on a voyage from Sweden to Hartlepool in England when a fire started in the machine room. Attempts were made to extinguish the fire by filling the machine room with CO2. They failed and the crew was forced to shut down the engines. The cargo manifest did not have the proper information and rescue personnel boarded the vessel to fight the fire unaware of the presence of 40 tonnes of sodium chlorate stowed within two containers on the lower deck. When this was found out the ship was quickly abandoned, a one-mile exclusion zone was established and the salvage tugs left the scene. After a few days an explosion blew out the side of the ship, causing it to roll over, capsize and sink.
Explosion in edible oil tanker Champion trader, Mississippi river, USA, 1998: an explosion caused the escape of 460 tons of palm oil in the Mississippi river. No human casualties were reported.
Salvage of the Egyptian cargo boat Junior M, Brest, France, 1999: Faced with a flooded hold and a pump failure, the vessel, transporting 6,900 tonnes of ammonium nitrate in bulk, was diverted towards the harbour of Brest and forced in by the Maritime Prefect, against the will of the port authority. Its cargo was unloaded under tight security and evacuated by train.
Heating of iron balls cargo of Adamandas, La Réunion, France, 2003: The *Adamandas* bulk carrier, transporting 21.000 tons of deoxidized iron balls noted an increase temperature of its loading. It sailed to La Réunion as the only place in the Mozambique strait where it could seek assistance. In front of the risks for the population, the authorities moved the ship 10 nautical away, scuttled it and sank it by 1.700 m of depth

Table 3: HNS incidents resulting in fire and/or explosion without human casualties

As a whole, the incidents in tables 1 to 3 show that the risks for Man related with fire and explosion concern mainly the ship crews and salvors onboard. But there are indeed exceptions, namely the crew and passengers of the ferry boat Moby Prince colliding with the tanker Agip Abruzzo, and port workers and inhabitants of Texas city and Brest affected by the explosions of the cargoes of ammonium nitrate of the Grandcamp and Ocean liberty. Those last two incidents show up to what point the explosion of an HNS cargo can affect both the port and the city around. Clearly, some HNS are far more dangerous than oil as regards risks for human health related with fire and/or explosion.

In the light of the incidents presented here, the weight of the responsibility lying on the shoulders of the responding authority shows clearly in the decisions made:

- to enter in the port of Brest the Junior M with its cargo of wet ammonium nitrate,
- to tow away from the port of les Galets and sink the Adamandas with its cargo of oxidizing iron balls,
- to evacuate the Korsnäs Link ferry in fire with 40 tonnes of sodium chlorate onboard, build an exclusion zone around it and let it sink,
- To let the Val Rosandra burn with its cargo of liquefied propylene and help it sink offshore,
- To sink the Stanislaw Dubois with its cargo of calcium carbide, caustic soda and organic peroxide

3. RISKS RELATED WITH SPILLS OF TOXIC, CORRROSIVE AND/OR CARCINOGENIC PRODUCTS

3.1. Oil spills

The risks considered here concern the effects of direct contact with the product, through eyes, skin and lungs. There are frequent claims of headache, skin and lungs irritation, breathing problems, from people who have been exposed to spilled oil, whether as local inhabitants or as responders. But there are no records of populations being evacuated as a protection against a toxic cloud of oil vapours. On the long run, there are frequent announces, after a spill, that epidemiologic studies are needed to ascertain the relation between the carcinogenicity of some compounds and cancer people who have been exposed will develop. But there is few and little convincing such studies years after the spill.

7 oil spills in which the subject has received particular attention are briefly described in table 4 hereafter.

Stranding of the oil tanker Exxon Valdez in Prince William Sound, Alaska, USA, on 24 March 1989: in front of that crude oil spill of unprecedented size in the USA (some 40 000 tons), By the end of 1989, Exxon had employed over 11,000 cleanup workers, 45% of whom worked directly on the oiled beaches. According to Exxon's clinical data, 6,722 of those workers reported upper respiratory infections: a symptom of chemical poisoning from inhalation of oil mists. It is claimed that, for many workers, these symptoms persisted and worsened over the next decade. Exxon had an extensive library on health effects from inhalation of oil vapours, mists, and aerosol. But it is claimed that Exxon did not tell the workers about the risk of oil mist and PAH inhalation or offer trainings or protective gear. It is claimed in addition, that cleanup solvents contained health hazards known to cause respiratory damage and central nervous system disorder; chronic liver, kidney, and blood disorders; immune suppression; and acute skin disorders. Toxicologists discovered high levels of petroleum hydrocarbons in cleanup workers' blood samples, similar to levels found in people working in oilfields in the Gulf War. Follow-up medical surveys conducted by Yale Medical School's Department of Epidemiology and Public Health document chronic symptoms of chemical sensitivities for exposed Exxon cleanup workers. The report states that, to this day, some Exxon cleanup workers suffer from headaches, nausea, seizures, and cancer. Yet, only one worker out of the 1811 who filed a health compensation claim has successfully litigated against Exxon for that matter. All other cases have been dismissed on technicalities.
Stranding of the oil tanker *Braer*, coast of Shetland, UK, 5th January 1993: Incapacitated by an engine failure, the Braer stranded on the exposed, rocky southern shore of the Shetland, in a storm, was dismantled by the swell and spilled its entire cargo of 87,000 tons of light Gulfax crude oil, and fuel/diesel oil. Aerosols of oil were transported by winds in excess of 100 km hour to houses and lawns over the island. Inhabitants suffered of a strong smell of oil and reports were produced claiming irritation of eyes and noses. A study, started on 13 January 1993, confirmed the anecdotal reports of certain acute symptoms. But no evidence of pulmonary, haematological, renal, or hepatic damage was detected at the population level. Toxicological analysis of samples from exposed people did not produce levels known to affect human health.
Heavy fuel spill of the tanker Erika, wrecked off the French Finistère, 12 December 1999: The spilled fuel included a complex mixture of polycyclic aromatic compounds (PAH) of high molecular weight, some of which are known to be genotoxic, inducing carcinogenic lesions in laboratory animals. An independent laboratory advised that volunteers manually recovering oil or cleaning birds were putting their lives in danger and many left the beaches. DNA adducts, reflecting genotoxic effects, are used as biomarker of early pollution. A genotoxic impact of the fuel on fish was assessed by studying the presence of DNA adduct in the liver of immature fishes (*Solea solea*) from four locations of the French Brittany coast, two, six and nine months after the disaster. Two months after the spill, a high amount of DNA adducts was found in samples from all locations. In September, no significant difference was observed between the locations
Sinking of the oil carrier MT Solar I, near Guimaras in Philippines, August 2006: that incident caused a spill of some 300 m3 affecting 20 coastal communities in Guimaras and threatening 27 in Iloilo and 17 in Negros Occidental. The spill is claimed to have caused health problems to the people in the area. Many have fallen sick, skin irritation and respiratory problems being the main complaints so far: It has been claimed that a villager from Barangay Lapaz died from cardio-respiratory problems after inhaling fumes of oil sludge. But no such claim has been recognized as valid to date.

Grounding of the oil tanker Tasman Spirit in Karachi harbour channel, 27 July 2003: The tanker grounded with 67,000 tonnes of Iranian crude on board. The hull was perforated and around 27,000 tonnes of crude were spilled. Lightering operations allowed 13,000 tonnes of oil to be recovered on 13 august, after which bad meteorological conditions interrupted operations and split the vessel in two. Seaside Karachi residents complained of feeling unwell. A TV news crew had to be hospitalized after inhaling toxic vapours while filming on a beach. According to the chemical properties of the oil, approximately 11000 tonnes of volatile organic compounds would have entered the air after the spillage. A pungent odour was reported to be perceptible at a distance of one km from the beach area. It was estimated that residents of Shireen Jinnah Colony, Seaview and Clifton as well as workers and picnickers were exposed to 40 to 170 ppm of volatile organic compounds for at least 15 to 20 days. Doctors related health complaints, with a higher incidence of respiratory problems among residents suffering from asthma, irritation of eyes and skin.
Oil spill caused by Israeli bombing of a power plant and oil depot, Jiyyeh, Lebanon, July 2006: Some 10,000 tonnes of heavy fuel oil for power station were spilled from the Jiyyeh power utility after Israeli aircraft bombarded it on July 14th. More has leaked out after the attack and at least 75 miles of coastline in Lebanon and Syria have been polluted. According to the UN Environment Programme (UNEP), the presence of the fuel oil on the coasts of Lebanon and Syria exposed people in the zones affected to a heightened risk of cancer, on the consideration that heavy fuel oil for power stations contains substances such as benzene, categorised as a class one carcinogen. No epidemiologic study seems to have been undertaken
Heavy fuel of the oil-tanker *Prestige* sank off the Galician coast, 13 November 2002: In the same way as that of the Erika, the fuel spilled in the wreckage; coming from Russia, included a variety of PAHs classified it as human carcinogens. Several studies reported acute health problems among contract workers and volunteers involved in the clean-up, in Galicia, Asturias, Cantabria and the Basque country, as well as a rise of social upheavals and mental health disorders among victims of the disaster. A study analyzed in particular the effect of the accident on health-related quality of life (HRQoL) and mental health in the affected population. Using random sampling stratified by age and sex, 2700 residents were selected from 7 coastal and 7 inland Galician towns. The results showed coastal residents as having a lower likelihood of registering suboptimal HRQoL values in physical functioning and bodily pain, and a higher frequency of suboptimal scores in mental health. But one and a half year after the accident, worse HRQoL and mental health levels were not in evidence among subjects exposed to the oil spill, regardless of their exposure

Table 4: Claims of intoxicating/corrosive/carcinogenic effects of oil spills

The incidents above show a demonstrated fact, a presumption and a recurrent fear:

- the fact is that people exposed to a massive spill of oil including an important evaporable PAHs content, primarily pollution responders, but also coastline residents; may present noticeable respiratory problems in the weeks and at time in the months following the spill,
- the presumption is that those people might as a consequence develop for years increased sensitivity to asthma and related respiratory problems, as well irritation of eyes and skin
- the fear is that responders and coastal inhabitants would develop years after the spill a higher proportion of cancers that unexposed people, a perspective often envisaged in the months following a spill, with the recommendation to implement a well designed epidemiologic survey, which is either unimplemented or results in non conclusive information

An example of the last point is the synthesis paper by J. Pézerat (2009). The author mentions that investigations implemented after the Erika incident demonstrated the genotoxicity of the spilled fuel on human cells, through the induction of the formation of enzymes known to participate in the cancer process. He regrets that no investigation was implemented in the blood of workers exposed to the spill, for adduits between ADN and metabolites issued from the spilled fuel. And he finds it impossible, from the available data, to conclude on any quantitative assessment of the possible cancers to result from participation in spill response, beyond considering that the reality will certainly exceed the national health agency estimate of one cancer per 10 000 responders, to show after 2010 or 2020. Looking for a reference in a different situation, as a term of comparison, we

found a California EPA (1998) estimate that 4.5 in every 10 000 Californians are at risk of developing cancer because of exposure to diesel exhaust in their normal life, i.e. for 4.5 times the risk faced by Erika responders. In other terms, Erika spill responders who came from villages may have been exposed to some increased cancer risk, but responders who came from large cities may have in fact reduced their exposure.

3.2. HNS incidents

Fifteen incidents involving corrosive, toxic and/or carcinogenic HNS are summarized in table 5 hereunder

Sinking of the cargo ship Viggo Hinrichsen, Baltic Sea, Sweden 1973: That German dry cargo ship sank at a depth of 17 m, with a cargo of 234 tons of chromium trioxide and 180 tons of sodium dichromate. Chromium trioxide is a corrosive solid, a powerful oxidizer that decomposes by heat into free oxygen and may cause fire and explosion in contact with combustibles. It had started dissolving in water. The place was treated with 11 tons of Ferro sulphate, a reducing agent. The treatment did neither any good nor any harm
Sinking of the dry cargo ship Cavtat, Strait of Otranto, Italy, 1974: when that Yugoslav dry ship sank at a depth of 94 m, after a collision with the Panamanian bulk carrier Lady Rita, it had a cargo of 150 tons of tetraethyl lead (TML) in 500 drums on deck and 120 tons of tetraethyl lead (TEL) in 400 drums in the holds. TML and TEL are both poisonous liquids if skin is exposed or vapours are inhaled. Cargo salvage was implemented 2.5 years after the accident, following strong lobbying from scientists, politicians and mass media. 250 tons of TEL and TML (93%) of the cargo were recovered in a year.
Leak of ammonia while unloading the Belgian tanker René 16, port of Landskrona, Sweden, 1976: the ship was unloading ammonia in the port of Landskrona, Sweden, when an incorrect choice of hose produced a leak of about 180 tonnes of ammonia onto the quay. A large cloud covered the vessel and was moved by the wind towards a shipyard nearby. Ammonia is corrosive, with poisonous vapours. The cloud dispersed after about an hour. Two members of the crew were found dead on the quay.
Loss of Chlorine cylinders by the Sinbad in the north sea, 1979: the ship lost in bad weather 51 cylinders containing each on tonne of chlorine, a highly reactive, toxic and corrosive gas. 7 cylinders were rapidly located and recovered, 27 were found and destroyed in the zone 5 years later, 13 remained missing. There is no record of human impact
Loss of containers by the Testbank in a collision, Mississippi river delta, Louisiana, USA, 1980: when the container ship Testbank collided with the Panamanian bulk carrier Sea Daniel, 4 containers on Testbank were knocked overboard into the 11 m deep river. The containers of greatest concern carried 16 tons of pentachlorophenol (PCP) in 23 kg paper bags and 3 steel barrels (first reported 16) of hydrogen bromide (first reported as hydrobromic acid). Shortly after the collision, a white haze of hydrogen bromide, a corrosive, toxic gas, enveloped the ship. The crew secured the ventilation system and took shelter below decks. The white haze was carried by the winds into a village where the sheriff evacuated 75 residents from their homes. A safety zone was established, around the wreckage site
Leak of aluminium phosphide, Rio Neuquen, Port of Houston, Texas, USA, 1984: During unloading the Argentine container ship Rio Neuquen, a 20 foot shipping container with aluminium phosphide exploded and flasks containing aluminium phosphide leaked. The substance is a toxic biocide used as a fumigant to control insects. It reacts with water or atmospheric moisture to emit the highly toxic and reactive gas, likely to auto ignite and cause explosion, even at ambient temperature. After thorough evaluation, ocean dumping was considered the mot satisfactory option. During the operation, a longshoreman was killed by a flying container door and other men were exposed to phosphine gas.
Loss wheat cargo, Fenes, Southern Corsia, France 1997: After the general cargo vessel got stranded in small bay in the Lavezzi islands, spilling 2 600 tonnes of edible, fish didn't eat it as expected an wheat fermentation in an anoxic environment resulted in the release of hydrogen sulphide (H_2S), a highly toxic gas which makes it necessary for intervening personnel to wear protective clothing and masks during an 8 months recovery operation.
Drums deterioration, Oostzee, Elba River in Germany, 1989: Fumes of epichlorhydrin (Toxic substance of a carcinogenic nature) leaking from the damaged drums on the Oostzee seriously damaged the health of the ship's crew. The toxic effects of this chemical incident had been extremely harmful to intervening personnel in the long term, as several years' later cases of cancer, probably linked to the incident, were diagnosed on several people, some who died soon after.

Engine failure, containership Dana Optima, North Sea, east of Esbjerg, Denmark, 1984 An engine failure aboard the Danish container ship, in a heavy storm, caused the ship to list and deck cargo to fall overboard. 80 drums (200 litres each) of the extremely toxic but little soluble pesticide dinitrobutylphenol sank to bottom, at a depth of 40 m. 4 months of extensive search by Danish and Dutch vessels equipped with side scan sonar, precision navigation equipment and a remotely operated vehicle (ROV) allowed to find and salvage 72 of the lost 80 drums. They had been damaged by fishing and salvage gear as well as by the high water pressure. Yet, no environmental effects were observed.
Leak of acid, dry cargo ship Julie A, Åarhus harbour, Denmark, 1989: the ship, moored in the harbour, reported a leak estimated between 1 and 5 tonnes from a tank of 300 tonnes of 33% hydrochloric acid on board. The leaked acid made its way to a ballast tank and threatened the bottom of the ship. After some trouble finding the appropriate equipment, offloading of the acid was initiated. Soon the stability of the ship was decreased the ship was moved to a dry dock and was dried from the acid through a hole drilled in the bottom.
Loss of containers, Santa Clara, coast of Cape May, New Jersey, USA, 1992: in adverse weather, the Panamanian container ship lost, some 30 nautical miles off the coast, 21 containers with 414 drums each of 374 pounds of arsenic trioxide, a biocide, very poisonous by ingestion and possibly by skin absorption, a known carcinogen. A single dose of arsenic trioxide no larger than the size of an aspirin tablet is lethal to humans. The drums were searched by sea and air. A specially designed recovery barge salvaged 320 drums of arsenic trioxide from the ocean floor.
Spill of fertilizers, Frank Michael, North of the island of Gotland, Baltic Sea, 1993: the German dry bulk carrier grounded and suffered severe bottom damage. Its cargo of 1,100 tons of non toxic solid fertilizer (Monoammonium Phosphate) started to escape and dissolve in the surrounding water. The time of the year and the favourable water turnover in the area reduced the risk for the environment and no mitigation action was taken.
Sherbro containers lost in the Channel, 1993: 88 containers were lost in a storm among which 10 loaded with hazardous material, mainly pesticides, including 188000 plastic sachets of thiocarbamate, a chemical reacting with water to form phosphine, a toxic gas. 91% of the sachets were recovered on the French, Dutch and German coasts. No human impact was reported
Gas tanker Igloo Moon , Key Biscayne, Florida, USA, 1996: The gas tanker Igloo Moon ran aground, due to an unknown reason, outside Key Biscayne with 6,589 tonnes of compressed liquefied butadiene (a chemical inhibitor was added to prevent polymerization). Liquefied compressed butadiene is flammable, reactive and a potential carcinogen. A hydrographical survey of the area was implemented to find the best way to bring another gas tanker alongside the Igloo Moon. 1,000 tonnes of butadiene were transferred to a lightering vessel, and the Igloo Moon was refloated with the flood tide.
Acid spill, Martina, Öresund, West of Kullen, Sweden, 2000: the chemical tanker Martina collided with a cargo ship broke in two and the stern part sank immediately. The rest of the ship, with a cargo of 600 tonnes of 30% hydrochloric acid, sank after a few hours. Two out of seven crew members were saved from the water. Due to the weather it was impossible to reach the ship during the first two days. As the hydrochloric acid is not a marine pollutant and not harmful in low concentrations it was decided that a monitor the release of the cargo. The bunker oil was considered as a threat to the marine environment and was pumped up.

Table 5: HNS intoxicating/corrosive/carcinogenic effects

The incidents above show a wide variety of HNS hazards. Corrosion is illustrated by the hydrochloric acid spills of the Julie A and Martina, the latter with structural damage to the ship and human casualty when she sank. Toxic vapours are illustrated by the ammonia spill of the René 16, the aluminium phosphide leak of the Rio Neuquen, the corrosive and toxic hydrogen bromide from the Testbank containers, the epichlorhtdrin from the damaged drums on the Oostzee. Situations in which the chemicals were left to dissolve in surrounding water are illustrated by the incidents of the Viggo Hinrichsen (chromium trioxide and sodium dichromate) and Frank Michael (monoammonium phosphate). Recovery measures to avoid future contamination by HNS trapped in a wreck or in lost containers and packages are illustrated by the incidents of the Cavtat (tetramethyl lead and tetraethyl lead), Sinbad (chlorine), Dana Optima (dinitrobutylphenol), Santa Clara (arsenic trioxyde), Sherbro (thiocarbamate) and Igloo Moon (liquefied butadiene). The chemical evolution in water of an edible product into a source of toxic gas is illustrated by the edible wheat spill of the Fénès (production of hydrogen sulfide).

Finally, the only effects for which there are no more than unconfirmed fears are the carcinogenic ones: there are even less epidemiologic studies in that field for HNS spills than for oil spills. .

As a whole, intoxicating, corrosive and/or carcinogenic effects on Man, really or presumably related with HNS spills, are far more numerous and diverse than those of oil spill. On that ground, HNS spills can be much more dangerous than oil spills of comparable importance.

4. RISKS REQUIRING NO DIRECT CONTACT: FOOD POISONING, RADIOACTIVITY, PSYCHO-SOMATIC DAMAGE

4.1. Oil spills

5 oil spills of particular interest as regards human impact without direct contact with oil are summarized below.

Stranding of the oil tanker Exxon Valdez in Prince William Sound, Alaska, USA, on 24 March 1989: in that incident, already mentioned in item 3.1. claims were filed by 20 communities in the oil's path for major social and psychological impact like depression and post-traumatic stress disorder. These impacts were examined in a population-based study of 594 men and women living in 13 Alaskan communities approximately one year after the spill occurred. The study reported declines in traditional social relations with family members, friends, neighbors and coworkers; in subsistence production and distribution activities, in perceived health status. It also reported increases in problems associated with drinking, drug abuse and domestic violence, in the number of medical conditions verified by a physician, in generalized anxiety disorder, post-traumatic stress disorder, and depression. Alaskan Natives, women, and 18-44 year olds in the low-exposed groups were found particularly at risk for psychiatric disorders following the oil spill. For the authors, the results suggest that the oil spill impact on the psychosocial environment was as significant as its impact on the physical environment. That worked was fiercely objected to by Exxon experts.
Explosion of the Piper Alpha oil production platform, North Sea, July 1988 : Only 59 out of the 226 men onboard survived. A study implemented by the psychiatric team (Ross, 2008) that first responded to the disaster showed that the survivors were suffering in a variety of ways: shock and denial, depression; flashbacks (re-enactments in which they saw, heard and sometimes even smelled the awful things they had experienced), problems at home (several marriages broke up), hyper-arousal (a nature's way of making sure you are ready for the next disaster) which some dampened with alcohol. On the 10th anniversary of the disaster, 36 survivors agreed to give interviews or complete questionnaires. Almost all reported psychological problems, 28 said they had difficulty in finding employment following the disaster (it looked like some offshore employers regarded survivors as bringers of bad luck who would not be welcome on other rigs and platforms), 70% had feelings of acute guilt, feeling they should not have survived when equally or more deserving workmates perished, some went on to play "Russian roulette" with their lives (driving fast and recklessly, taking up dangerous jobs or sport), but also some had learned things about themselves, changed their values and tighten relationships.
Capture and culture fisheries bans in oil tanker Aegean Sea grounding, La Coruna, Spain, 1992: The tanker ran aground while entering the harbour in a storm and broke in two, spilling nearly all its 80,000 tonne cargo of oil. About a third burnt and the rest heavily soiled the rias of Ares-Betanzos and el Ferrol, as well as some 100 km of coastline, impacting important shellfish harvesting and small scale fishing areas, mussel cultivation rafts and turbot and salmon farms in tanks and net pens. For the protection of consumers, fishing and marketing bans were implemented and, after sets of analyses and taste tests, the impacted stocks of cultivated species, amounting to some 20 000 tonnes were destroyed. Bans lasted from 3 months to 2 years, depending on the species, activity and area, decisions to continue or lift them being based on taste tests.
Stranding of the oil tanker *Braer*, coast of Shetland, UK, 5th January 1993: after the tanker got stranded, severe weather conditions intimately mixed the spilled oil into the water column and the mixture was carried by wind and currents mainly to the north and west, an area of intense salmon farming in net pens and commercial shell fishing activity (Lancaster, 2007). To protect consumers, a fisheries exclusion zone was established and. the contamination of the cultivated salmon was monitored; PAH rapidly accumulated up to levels of 14,000 ng/g wet weight salmon flesh a few days after the spill, compared with a mean value of 30 ng/g outside the zone. Month after months, batches of salmon that had reached market size without having

returned to baseline PAH level, were disposed of. The fisheries bans were progressively lifted, the longest, concerning scallops, lasting 3 years.
Spills from oil exploitation in the Niger river delta, 1999: Although oil companies operating in Nigeria are supposed to adhere to good oil field practices, implying that they will abide by the Institute of Petroleum Safety Codes, a history of disregard for human rights has led to large-scale human and environmental damage. A recent report (Wysham, 2001) considers that years of oil spills in the Niger Delta, which have yet to be cleaned up, amount to the equivalent of 400 million litres. This is attributed to the fact that the majority of the pipelines in the delta are situated above ground, rendering them susceptible to physical damage and corrosion. Pipelines weekly leakage is said to contaminate groundwater and destroy the soil, significantly decreasing crop yields. Fisheries, farms, mangrove swamps, rainforests and water have all suffered severe damage from oil, pushing tens of thousands of people to the brink of starvation

Table 6: Food poisoning and psycho-somatic damage by oil

Many more examples of fishing/marketing bans could have been given. Protection of consumer against the risk of poisoning or only unrest from the consumption of tainted seafood is common practice in oil pollution response. The examples of the Aegean Sea and Braer have been selected because the bans were particularly long and the stocks destroyed particularly important. They also illustrate the two different methods used to assess seafood contamination: either taste tests (Aegean Sea) or chemical analysis (Braer)

The Exxon Valdez, Piper Alpha and Niger Delta illustrate 3 completely different ways through which psycho-somatic damage can be generated : exposure to the vision of pristine areas and wildlife soiled by oil (Exxon Valdez), being among the few survivors of a blast (Piper Alpha) or living in an area chronically polluted by multiple spills (Niger delta). Those examples also illustrate the fact that psycho-somatic damage is far from being easily compensable.

4.2. HNS incidents

HNS incidents with food poisoning or radioactivity do exist, and 4 of them are summarized in table 7 below. But we could find no example of psycho-somatic impact. They do certainly exist. As an example, impacts comparable to those of the survivors of the Piper Alpha platform have beyond any doubt affected the survivors of the explosions of the Grandcamp and Ocean Liberty. But those impacts haven't been documented

Loss of uranium hexafluoride cylinders by ro/ro. Mont Louis, North Sea, Belgian coast, 1984: The French ro/ro Mont Louis collided with the car ferry Olau Britannia off the Belgian coast and sank in international waters, 15 m deep, with among her cargo 30 cylinders with 15 tons each of nuclear fuel uranium hexafluoride (UF6). A low radioactivity solid, UF6 reacts with water to form the highly corrosive and toxic gas/liquid hydrogen fluoride. The charter company contracted the salvage of the cargo, a task successively completed 40 days after the accident, under close monitoring by the Belgian authorities,
Capsizing and sinking of Perintis, English Channel, 13 March1989: In the ship cargo were 5.6 tonnes of the extremely toxic pesticide lindane and 1.6 tonne of permethrine and cypermethrine, pesticides both toxic to the marine biota. Precautionary samples were taken by the British and French authorities on fishing within 12 km of the presumed position of the pesticides container and on the landing of fish and selfish. The incident seriously disturbed fisheries in the central Channel for close to a month
Styrene spill of chemical tanker Chung Mu, South China, 1995: after a collision with another ship at the entrance of the port of Zhanjiang, the Chung Mu lost 230 t of styrene, a chemical known to taint fisheries product. An exploitation ban was set by the authorities and taint test were organized as a basis to ascertain the quality of the products and resume activity.
Overloading of chemical tanker Crystal Rubino, port of Hamina, July 2000: overloading resulted in a spill of 2 tonnes of nonylphenol ethoxylate. Port water started to foam and dead fish soon surfaced. The chemical being a sinker and dissolver, it was impossible to recover it. Seagulls ate the dead fish.

Capsizing of ferry Princess of the stars, Philippines, 2008: On 21 June, the ferry hit typhoon Fengshen and capsize 850 people onboard, off the coast of Sibuyan Island. Many passengers and crew died. Because of the presence of containers of pesticides onboard, a 5 km exclusion zone was set up around the wreck, where fishing and aquaculture activities were prohibited. A team of European experts came on site to assess the human and environmental risks. Samples around the wreck showed no water pollution and the fishing/aquaculture ban was lifted

Table 7: food poisoning, irradiation and psycho-somatic damage by HNS

The risk of seafood consumers poisoning by HNS is well illustrated by the Chung Mu, Ievoli Sun and Princess of the stars incidents, implying styrene (the first two) and pesticides (the last one), and the Crystal Rubino incident shows waterfowl feeding on seafood killed by a spill.

The risk of exposure to radioactivity is ironically illustrated more by the Mont Louis incident as a risk of toxic cloud than actual radioactivity.

5 DISCUSSION

This review of the available literature on past oil and HNS spills by nature of impacts on human health does not support a global assessment that the risks are higher in all circumstances either with oil or with HNS. The assessment has to be made by type of risk.

Risks related with fire and explosion are non-existent to very limited with many HNS; existent and (save for exceptional situations) limited to those onboard the ship for oil, important and with potential dramatic consequences kilometres around for some particularly reactive HNS.

Among risks related with toxicity, corrosivity and carcinogenicity, the only one of notable importance with oil is carcinogenicity; but there would be a need for more well designed and objective epidemiologic studies to clarify the actual importance of that risk. HNS spills illustrate a comparable pattern as regards carcinogenicity but, on the contrary, they present a wide range of toxicity and corrosivity related impacts.

Among the risks requiring no direct contact, namely seafood poisoning, radioactivity and psycho-somatic damage, oil is clearly concerned by seafood poisoning, unconcerned by radioactivity, and a subject of heated debate as regards psycho-somatic damage. Some HNS are concerned with seafood poisoning, some others may be concerned with radioactivity, and the question of their concern with psycho-somatic damage is open for discussion.

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