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HAZRUNOFF PROJECT

"Integration of sensing and modelling technologies for early detection and follow-up of hazmat and flood hazards in transitional and coastal waters"

Feedback on past incidents in transitional waters

Funded by European Union Civil Protection and Humanitarian Aid

WP	4, Task 4.2.1
Action	Report – Feedback from past incidents
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authors	Cedre
participants	All

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Table of figures

Table of photos

INTRODUCTION

This report details the works undertaken by the Centre de Documentation de Recherche et d'Expérimentations (Cedre) to carry out a review and analysis of past accidents in transitional waters under Task 4.2.1 of Work Package 4.

Work Package 4 aims to contribute actively to efficient preparedness and response to floods and hazmat spills in inland and transitional waters, through the analysis of past accidents worldwide to identify characteristics and sources of these incidents. For this analysis, the data recorded in Cedre data base come from all available sources, specialized press and websites, conference acts, scientific publications as well as data from IOPPC Funds and insurance technical reports (ITOPF).

This presentation of past accidents data will be completed by a presentation and feedback on two incidents, one concerning diffuse pollution during a major flood and the other having affected an estuary. This cases allow to highlight some difficulties encountered.

Background

Main estuaries associate important rivers and transitional waters (coastal embayment, delta), associated with flood risks and potential for hazmat incident due to the presence of a wide range of activities, such as energy, chemical or oil facilities (refineries), large storage of various products, shipyards, ship traffic with liquid cargo etc…

What are the characteristics of hazardous substances spills in estuaries and inland waters, their frequency, the type of products and volumes involved, the causes of incidents? The analysis presented in this report is based on an inventory of incidents followed by spills in rivers and estuaries over a twenty year period (1998 - 2008), occurred worldwide and for which sufficient information was available. Despite these numerous sources, the consistency of incidents reporting is not the same among all countries, so completeness is not possible.

REVIEW OF HAZMAT SPILLS WORLDWIDE IN RIVER AND ESTUARIES

Characteristics of spills of any volume over the period 1998 – 2018

SPILLS FREQUENCY CONSIDERING ALL HAZARDOUS SUBSTANCES

During the twenty years period considered, 1593 incidents followed by spills, of any volume, were reported in inland waters and estuaries, 711 of which occurred in Europe. The largest share of the twenty year period appears to be oil (1150 events, 72% of events), then chemicals (23%) and far less organic and mineral effluents (respectively 3 and 2 %) (Fig. 1).

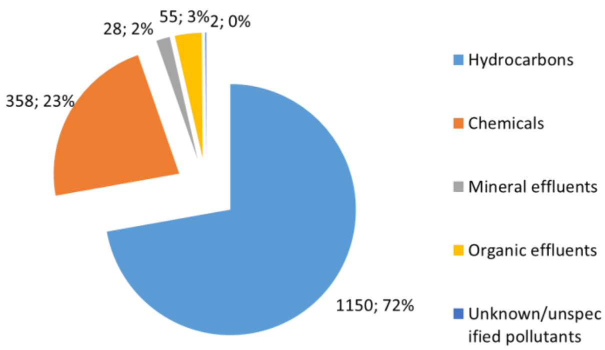

Fig. 1 *Spill frequency by product type (1998 - 2018, any volumes)*

SPILL FREQUENCY BY OIL TYPES

The type of oil spilt is crucial information, as the response strategy and the response techniques will depend on the physico-chemical characteristics of the oil.

As shown in Fig. 2, ***light refined products*** represent the great majority of the 657 light refined oil incidents worldwide (57%), 334 of which are reported in Europe. ***Crude oil spills*** represent 249 incidents worldwide (more than 21%) but only 14 incidents in Europe. For the majority of these crude oil spills (18%), there is no indication of the density of the product, which is an important parameter affecting the behaviour and fate of oil. In fact, in transitional waters as the salinity decreases with the input of the river flow, the tendency for oil to sink increases. This process is reinforced by turbidity.

For nearly 20% of oil spills reported there is no indication on the type of oil involved.

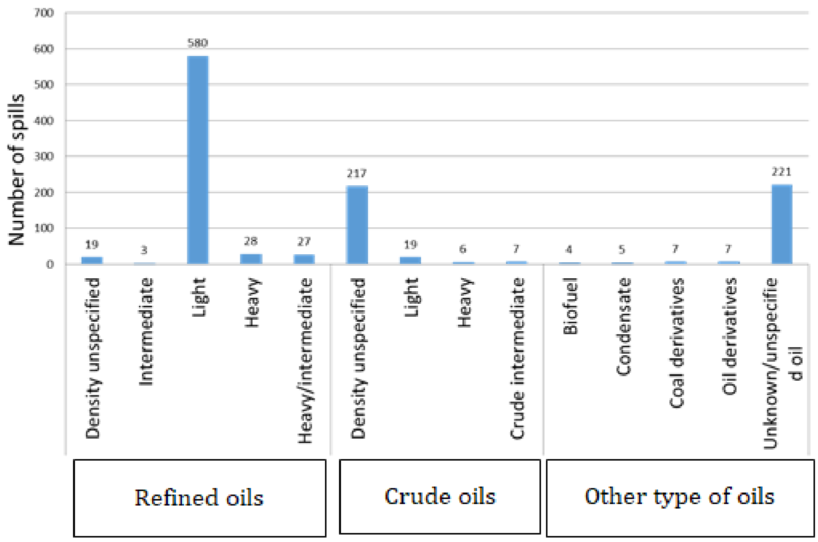

Fig. 2 *Number of spills by oils types (1998 - 2018, any volumes)*

SPILLS FREQUENCY BY CHEMICAL TYPES

The distribution of chemical types involved in the incidents reported (Fig. 3) indicates that ***mineral oil*** represents the great majority of spills, 87 incidents (24%), roughly half of them (46) occurring in Europe. The analysis emphasises the diversity of chemicals (acids, alkalis, synthesis chemistry, petrochemicals, liquid solutions of various natures, phytosanitary/pesticides, biocides).

The lack of information on the nature of the product can be noted for a significant part of the chemicals spilled.

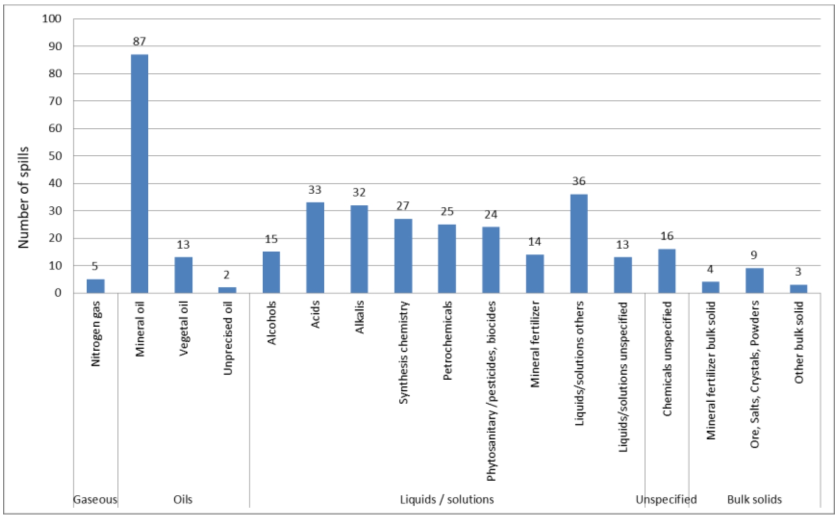

Fig. 3 *Number of spills by categories of chemicals (1998 – 2018, any volumes)*

SPILL FREQUENCY FOR OTHER TYPES OF SUBSTANCES

Amongst the other types of hazardous substances spilled in rivers and estuaries worldwide (Fig. 4), the frequency of incidents is of the same order of magnitude for agricultural domain (essentially ***slurry*** represented by 25 incidents in Europe), agrifood domain (17 incidents represented by processed waters, food liquids or solids and by-products), industrial activities (22 incidents due to processed waters, organic industry by-products, combustion residues, etc…). The mining industry has a lower contribution in term of frequency of spills (sludge, contaminated waters).

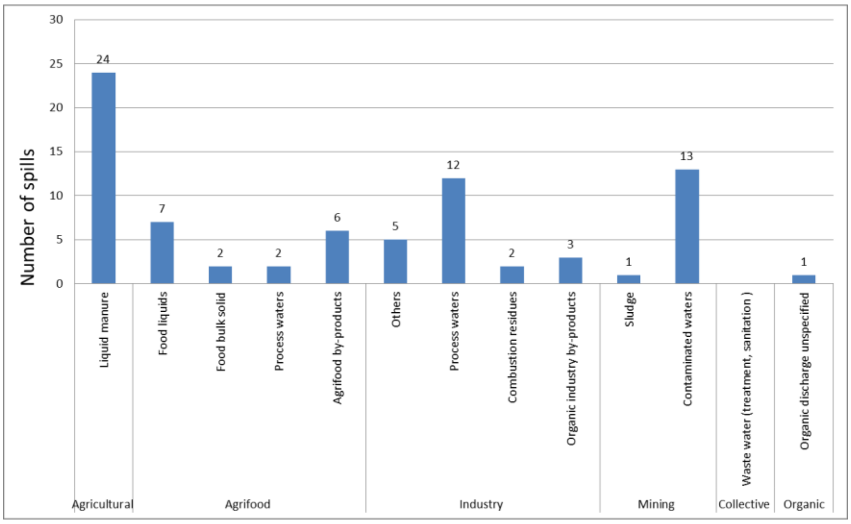

Fig. 4 *Number of spills by other types of substances /activities (1998 - 2018, any volumes)*

CUMULATIVE SPILLED VOLUMES CONSIDERING ANY HAZARDOUS SUBSTANCE

Over the twenty years considered, in term of volume spilled worldwide, ***mineral industry incidents*** are responsible for the main cumulative volume of around 12 million tons (Fig.5). In Europe, 4 incidents were reported during this period, and as an example, one major spill occurred in Hungary in 2010. This incident contributed for 1 500 000 m^3 of toxic mining sludge following a breakage in a basin retaining wall.

Oil spills represent a cumulative volume close to 2 million tons, ***organic matters spills*** represent 111 000 tons and ***chemicals*** ones, nearly 40 thousand tons.

Depending of activities and products, **typical spills volumes** vary a lot. The estimated median volume of spills for the period is of around 10 000 tons for mineral activity incidents, 38 tons for organic matter spills, around 11 tons for oils, and 5 tons for chemicals (Fig. 6).

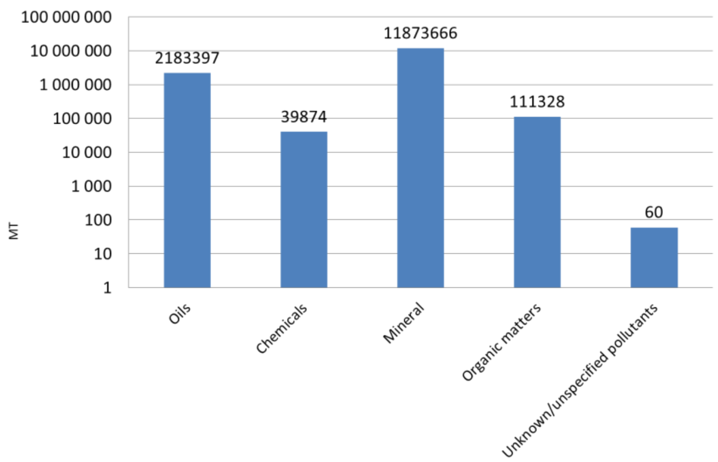

Fig. 5 *Cumulative quantities spilt by categories of products (1998 - 2018, in metric tons (MT)*

Typical spill / type of pollutant	Oil	chemicals	Mineral	Organic matters	unspecified pollutants
Median quant. (MT)	11	5	9 463	38	N/A

Fig. 6 *Typical spill volumes by categories of products (1998 – 2018, in metric tons (MT)*

ORDER OF MAGNITUDE OF SPILLS BY TYPES OF POLLUTANTS

OIL SPILLS

Amongst the 1150 incidents followed by ***oil spills*** reported worldwide for the period, the majority (638 spills, namely 55%) is represented by small spills of a volume under 10 m^3, half of which are under 1 m^3 (Fig. 7). For these small spills, 40 % of the incidents occurred in Europe (383 spills).

The volume is comprised between 10 and 100 m^3 for 250 reported oil spills worldwide (22%), among which the contribution of Europe is of less importance (43 incidents in Europe and 207 in the rest of the world).

Large oil spills (between 1000 and 10 000 m^3) represent 51 cases, i.e. 4% of the spills reported. Pipeline incidents are the main source of large oil spills (31 cases) with an important contribution of North America (where oil activity is important and incidents well reported) and South America (guerilla impact). Two incidents were reported in Asia and in Africa, one in Europe (Russia) and one in Israel.

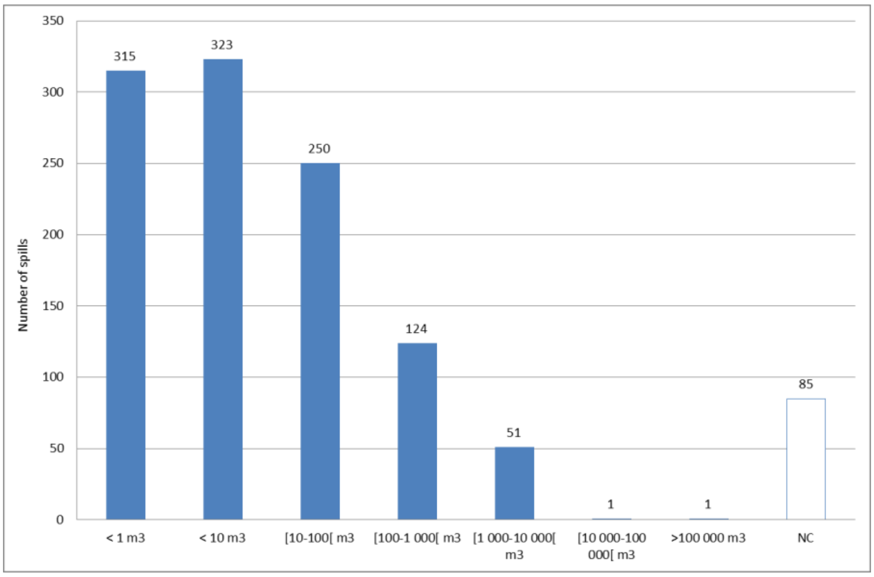

***Fig. 7* Oil**: *number of* spills *by categories of magnitude (1998 - 2018, any volumes)*

CHEMICAL SPILLS

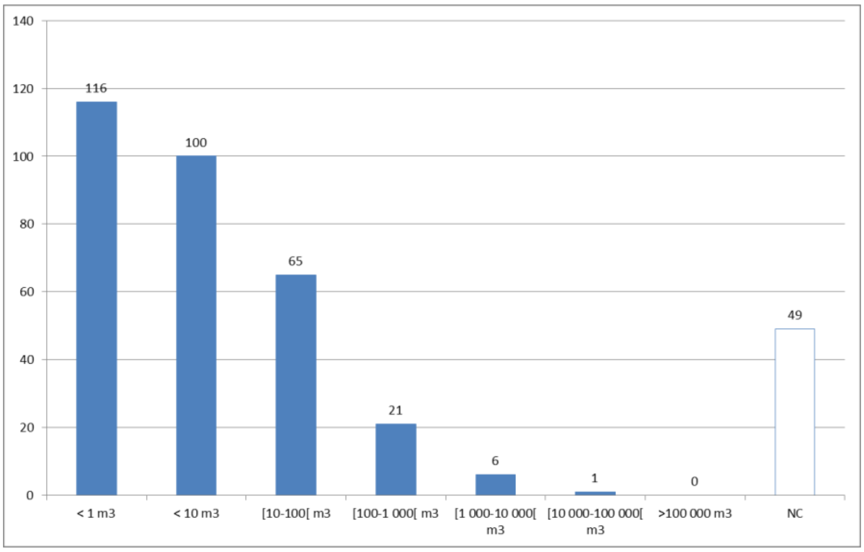

***Fig. 8* Chemicals**: *number of spills by categories of magnitude (1998 - 2018, any volumes)*

For the period 1998-2018, 358 ***chemical spills*** were reported worldwide (Fig.8), 176 of which occurring in Europe.

One major chemical spill occurred during this period (2003) in Brasil in a wood-pulping factory, where a reservoir dam broke, followed by a 500 000 m^3 leakage. The toxic waste containing caustic soda, chlorine and lead affected around 200 km of rivers to *Paraiba do Sul* estuary and Atlantic Ocean. Two rivers were concerned by cut off of water supply to 500 000 citizens in three of Brazil's states near Rio de Janeiro and water supply was cut for 112 plants.

6 chemical spill incidents of a magnitude of 1000 to 10 000 m^3 were reported in the world, involving mineral matters or fertilizer (amonitrate) and one reported in Europe (France) due to the overflow of extinguishing waters from an industrial plant.

For incidents of a magnitude between 10 and 1000 m^3 of the 86 reported, 18 occurred in Europe, for which products are highly variable and industrial plants main sources. Trucks, barges, tankers sources are more occasional or less reported (trucks).

MINERAL MATTER SPILLS

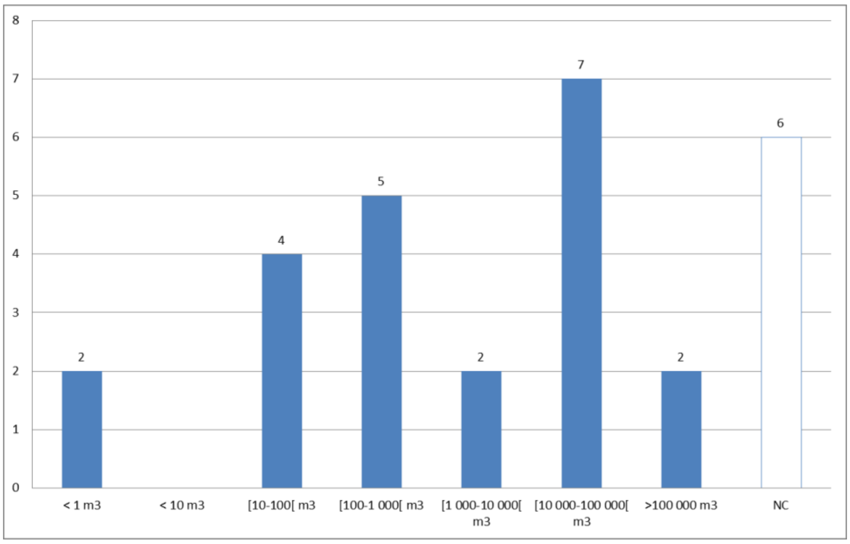

Fig. 9* Mineral matter: *number of spills by categories of magnitude (1998 - 2018, any volumes)

Mineral matter spill incidents often lead to large spills (Fig.9). These events are mainly linked to the mining industry and due to breaches in containment basins or, for a few cases, resulting from overflow due to rain and flood.

ORGANIC SUBSTANCES SPILLS

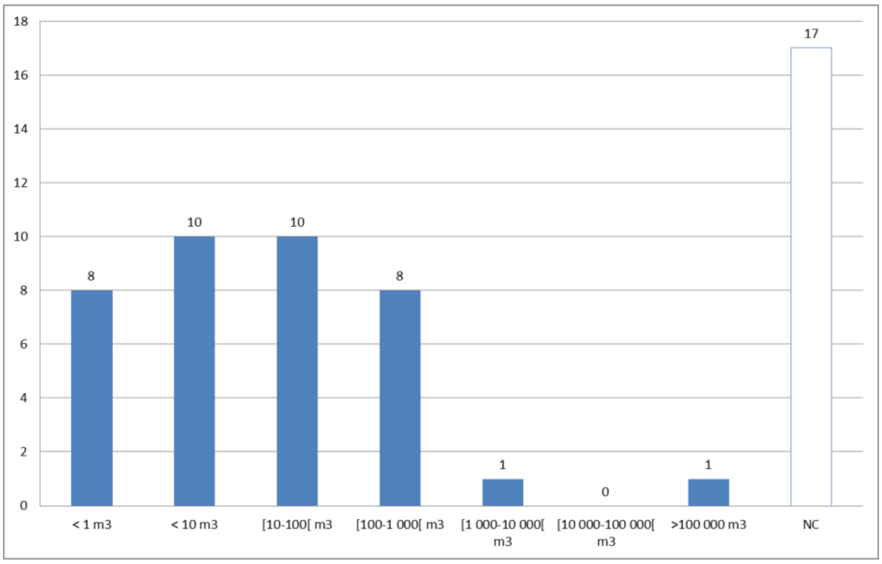

***Fig. 10* Organic spills (agribusiness, agricultural, industry, waste waters):** *number of spills by categories of magnitude (1998 - 2018, any volumes)*

Organic spills magnitude is mainly under 100 m^3 (Fig10). Almost all incidents reported occurred in Europe. The main source is agricultural activity (24 cases on 55 reported), the agribusiness industry and then, few cases due to the paper industry and collective sewage treatment plants.

Characteristics of spills over 10 tons over the period 1998-2018

SPILLS FREQUENCY CONSIDERING ALL HAZARDOUS SUBSTANCES

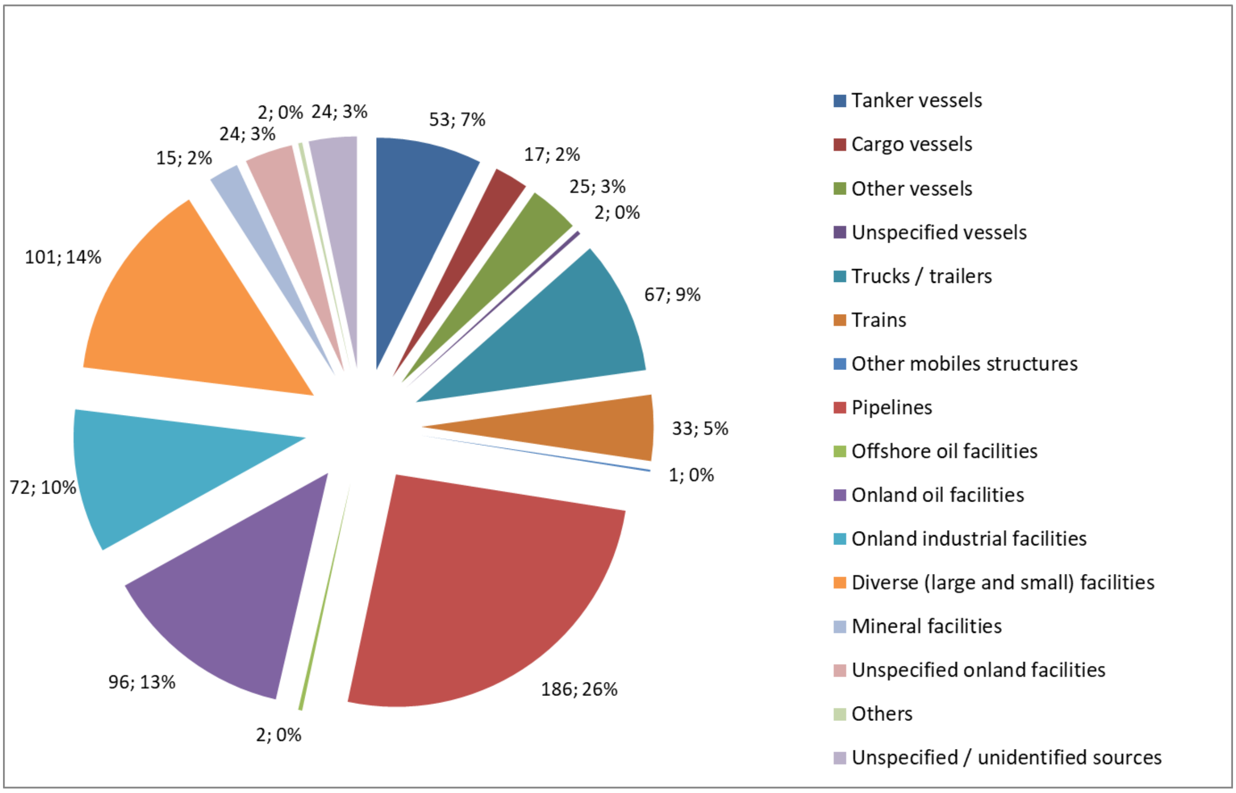

Fig. 11 *Spills number and frequency by source for all type of pollutants (1998 - 2018; vol. > 10 MT)*

Over the last twenty year period, worldwide, ***for all type of pollutants***, 720 incidents followed by significant spills (≥10 tons) were identified in inland waters and estuaries (Fig. 11) representing an amount of 14,2 million tons of hazmat with a vast predominance of mineral matter (nearly 12 million tons for 26 incidents). Aside from this majority of mining-related spills, the largest quantities spilt are oils (around 2 million tons for 513 events), organic matter (111 thousand tons) and chemicals representing 39 thousand tons for 142 spills.

Pipelines are the most frequent sources (26%), ahead of onland oil facilities (13%). However when considering all the onland facilities (industrial, oil etc…), they represent all together 40% of spills. Vessels represent 12% of spill sources, while trucks and trains represent 14%.

Among the 720 incidents, 180 were reported in Europe (98 from diverse onland facilities (industrial, storage, treatment plants ...), 15 from pipelines, 14 from onland oil facilities, 19 from all type of vessels, 13 from trucks and trains, 3 from mining effluent retention ponds). In 18 cases, the contamination source of rivers could not be identified.

OIL SPILLS >10T

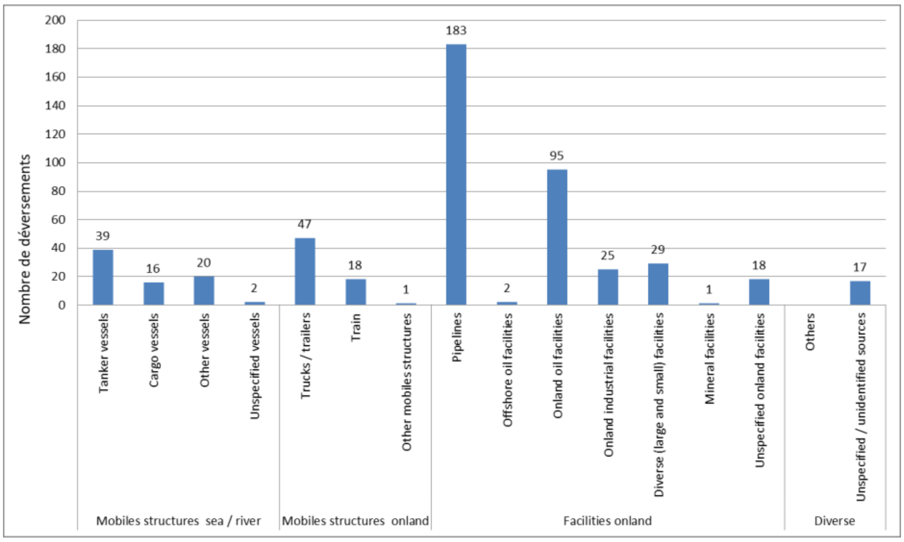

Fig. 12 *Frequency of* ***oil spills*** *by type of sources (1998 - 2018, vol. > 10 MT)*

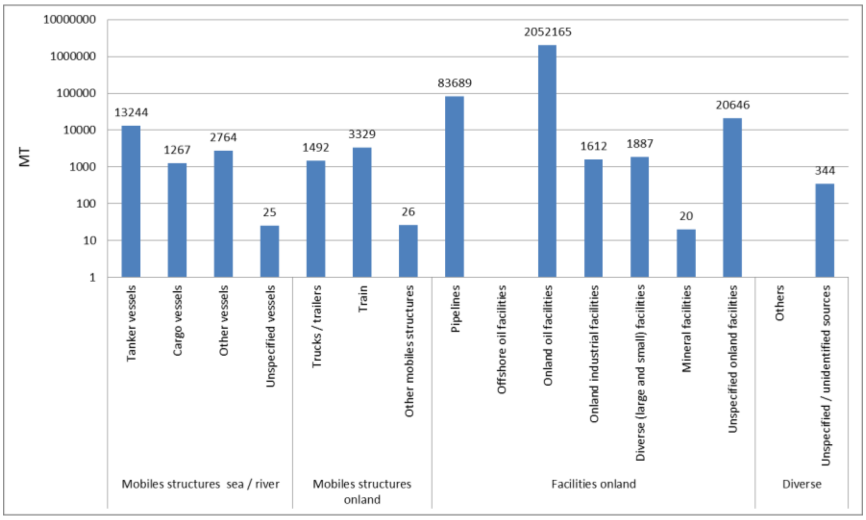

Fig. 13 *Cumulative volume of* ***oil*** *spilled by sources (1998 - 2018, vol. > 10 MT)*

In term of frequency of ***oil spills*** over 10 tons reported worldwide, pipelines are the most frequent source (183 incidents), well ahead of onland oil facilities (95 incidents) or vessels (77 incidents) or trucks (47) (Fig. 12), but in term of cumulative quantities spilt (Fig. 13), onland sources are responsible of the largest cumulative volumes, with oil facilities representing the main source (about 2 million tons), pipelines 83 689 tons, trucks and trains 4 821 tons, while in estuaries and rivers vessels of all categories (tanker, cargo etc..) represent 17 300 tons.

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CHEMICAL SPILLS >10 T

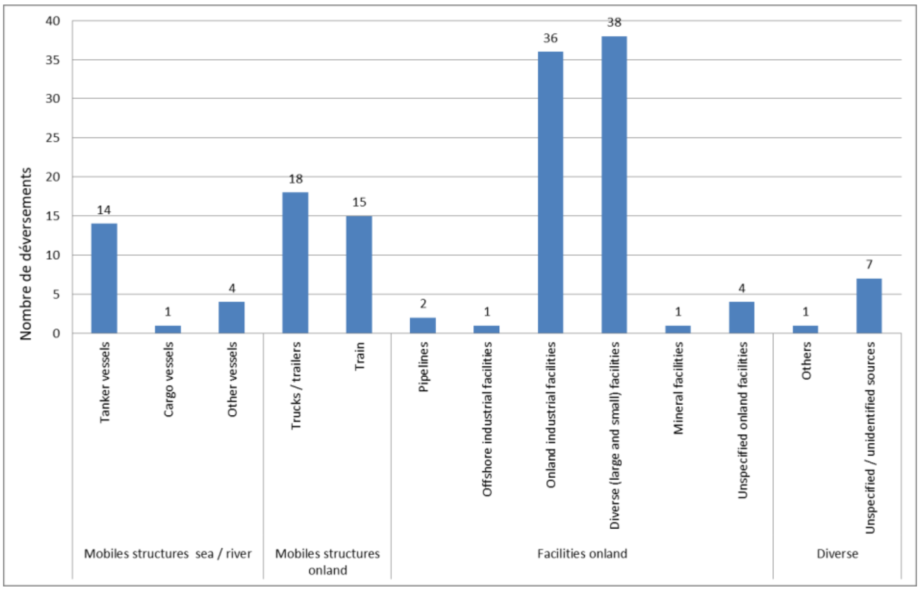

Fig. 14 *Frequency of* ***chemicals spills*** *by type of structures (1998 - 2018; vol. > 10 MT)*

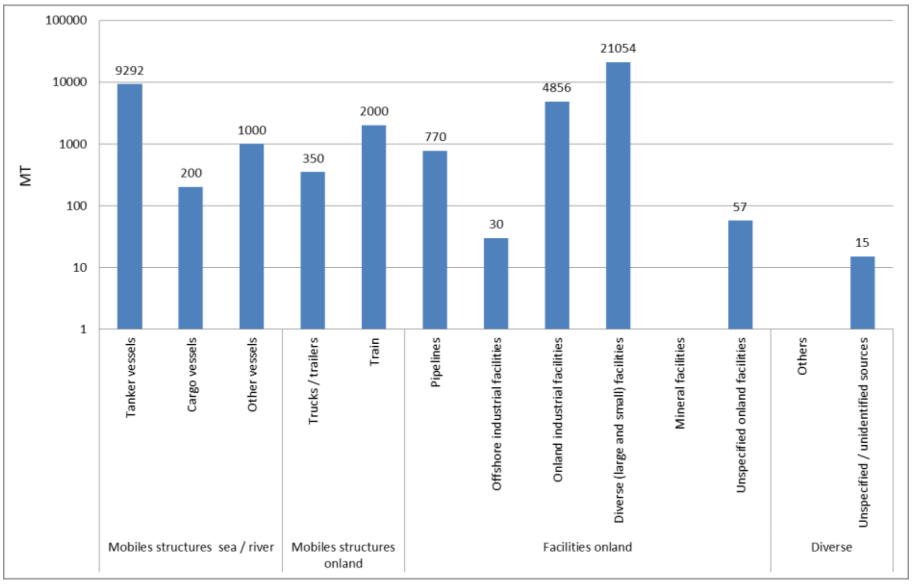

Fig. 15 *Cumulative volume of* ***chemicals*** *spilt by sources (1998 - 2018, vol. > 10 MT)*

Over the twenty year period, worldwide (Fig. 14 & Fig 15), onland industrial plants are the main sources of ***chemical spills*** (79 spills and 25 thousand tons), then vessels (19 events and 10 thousand tons) and overland transport (33 events and with

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approximately the same frequency from trucks or trains representing 2 350 tons spilt, with incidents of a greater magnitude for trains (85% of the volume spilt).

In Europe, 46 chemical spills events were reported, 35 from onland facilities among which 9 from chemical plants and 26 from a great variety of activities (agricultural, sewage treatment, storages and warehouses…), 2 from trucks, 4 from vessels. For 5 events the sources remained unidentified.

Events and causes of hazmat spills>10 tons over the period 2004-2018

An analysis of events and causes of incidents having occurred worldwide was made for the period 2004 -2018.

TYPE OF EVENTS

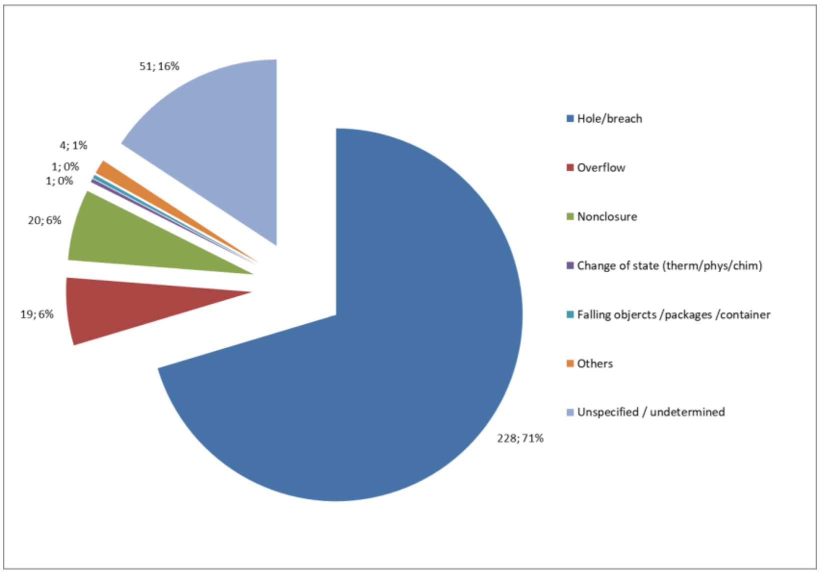

Fig. 16 *Spill frequency for all products by type of events (1998 - 2018, vol. > 10 MT)*

The most frequently reported incidents worldwide are breaches or holes in structures (approximately 71% of events), the type of events remains unknown for 16% of cases, then, non-closure and overflow events represent each 6%.

CAUSES

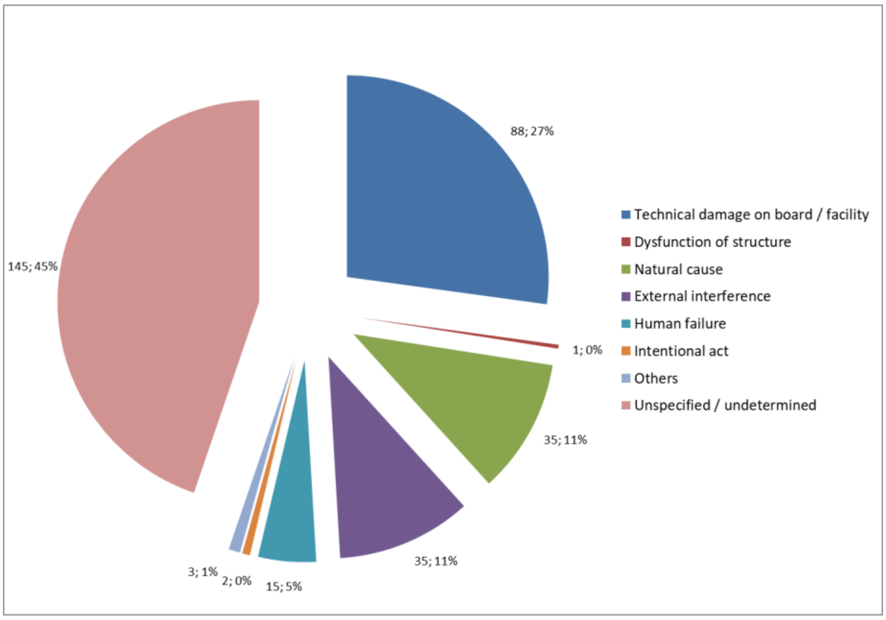

Fig. 17 *Frequency of spills by type of causes (1998 - 2018, vol. > 10 MT)*

Analysis of the frequencies of each cause (Fig. 17) shows that the cause was unknown or unspecified in 45% of events. Technical failure is identified as the source of around 27 % of the incidents recorded and it can be noticed that natural events are reported as the cause of 35 events (11%). Among these natural events, stormy rain and flood represents the majority of causes (26%) the rest of these natural causes are related to landslide.

FEEDBACK ON SPILL CASES IN ESTUARIES AND RIVERS

Example of diffuse pollution due to flooding in north-east France (2016)

After a very rainy month of May 2016, with nearly three times the average rainfall (Fig. 18) the soils were saturated with water which led to increased runoff and river overflow in early June, after successive episodes of heavy rainfall. The flooding affected a large area in the French Centre, Ile-de-France, Picardy and Burgundy regions in particular, many important Seine tributaries were affected (Fig. 19). A peak with an elevation of water level of 6,10 m in one night was measured in Paris. The flood was characterized as a 20 years return period flood and more for upstream tributaries. The flood impact was registered until the Seine estuary.

Due to this flood, 163 municipalities have been declared in a state of natural disaster.

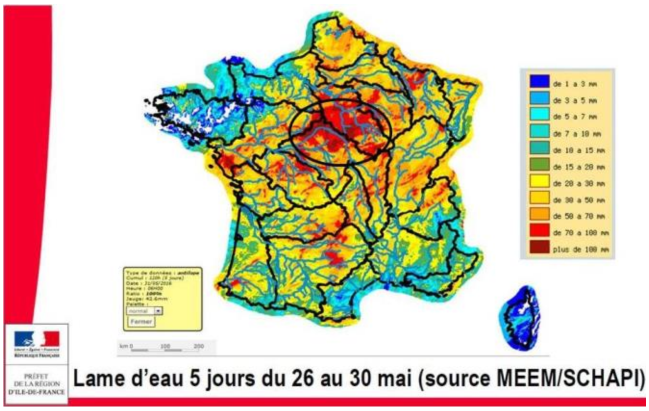

Fig. 18 *Area affected by heavy rain leading to flood (source Ministry of Environment/ Central flood forecasting support Service)*

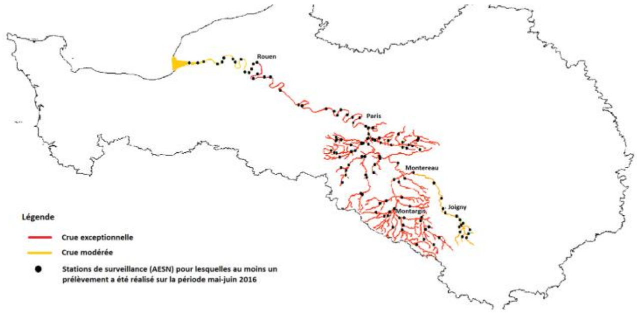

Fig. 19 *Affected tributaries of Seine water basin (source Seine Normandy Water Agency)*

The rainfall caused oil, among other products, to overflow from many different facilities: storage facilities for new or used oil, fuel tanks and other reservoirs, etc., in factories, warehouses, garages, residences, etc (photo 1). The pollutants spread across vast flooded expanses, including the riverbeds of many watercourses in spate, across very varied areas in terms of their amenities – natural and urban, public and private areas – contaminating many buildings and infrastructures (houses, blocks of flats, etc.), including underground facilities (car parks, cellars...) on their way. The local authorities and fire brigades – already heavily mobilised in responding to this exceptional flooding and managing the damage and risks generated, with human rescue being the number one priority, – had to face this "diffuse" pollution issue.

***Photo 1** Diffuse light oil contamination in flooded city of Nemours (source France2)*

Cedre was called upon in some departments at the request of the fire brigade, of authorities (*Préfecture*) or municipalities for several missions of a few days to a few weeks.

SITUATION ASSESSMENT AND FIRST RESPONSE MEASURES

Some main sources of pollution were identified (garages, warehouses), but flooded cellars with overflowing of heating fuel tanks were also reported and many scattered sources identified and often difficult to locate. Certain sites or homes were closed off, others were difficult to access due to the flooding, so the contamination assessment was difficult.

The pollution had spread very widely, carried by the flood waters as the water levels rose then fell. Helicopter overflights were conducted to monitor its spread along the watercourse, observe the containment systems deployed (floating booms) and recommend adjustments to optimise the set-up of these booms (photos 2 and 3).

Very soon, these investigations were further supported by surveys conducted on land, or even by boat when the streets were flooded. New recommendations on containment techniques and equipment were issued to support emergency response operations, in particular with advice on setting up custom-made barriers and filter systems, as classic booms were unsuitable for certain sites or configurations (photos 4 and 5).

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Many individual homes were affected by the oil, meaning that "door-to-door" visits had to be organised to obtain an accurate estimation of the extent of the pollution and to define ad hoc technical recommendations. These surveys were conducted jointly by Cedre with the municipality representatives and local authority staff, fire brigade personnel and other services, and proved to be particularly time-consuming.

Photo 2 *Containment of home heating oil escaped from private flooded cellars, by floating and sorbent booms (source Cedre)*

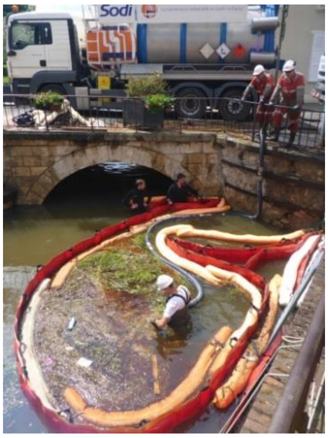

Photo 3 *Containment and pumping with vacuum truck on the river Loing in an old city center (source Cedre)*

Photo 4 *Custom-made barriers and filter systems for polluted small streams (source Cedre)*

Photo 5 *Preparing a cartridge with sorbents to place in a canalization manhole (source Cedre)*

The pollutants observed were mainly light fuels, in particular diesel or home heating oil, and oils such as used engine oil, while many other products present in cellars, sheds or workshops had also been released (agrochemical products, paint…) although

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the exact type or quantity could not be specified. Seveso-classified sites were protected and did not appear to have suffered any leaks or significant damage.

Another urgently needed action was to pump up the large volumes of contaminated water at flooded sites (cellars, underground carparks). Cedre assisted the Seine-et-Marne fire brigade in designing and building custom-made filtration systems (bins with a perforated base and filled with loose sorbent), in order to evacuate the water from these sites and release it into the natural environment (photos 6, 7, 8).

Photo 6 *Custom-made filtration systems in a bin with a perforated base (source Cedre)*

Photo 7 *Bin filled with loose sorbent (source Cedre)*

Photo 8 *Firefighters using the system to evacuate and filter oily water from a private house cellar (source Cedre)*

Health concerns rapidly emerged. A memo jointly produced by the Ile-de-France regional health agency (ARS), authorities, fire brigade and Cedre was released for the general public and provided instructions on what to do in the case of response actions in flooded and contaminated properties and cellars.

In addition, a sampling plan was defined to characterise the main types of oil pollution observed:

- Very heavily polluted areas of ground (with pollutant liable to be remobilised)
- Oiled embankments ;
- Areas of ground with visible traces of oil;
- Areas of ground with no visible traces of oil but located on premises where oil was reported during flooding;
- Recently emerged areas of ground with traces of oil on the water still adjacent to this area;
- Areas of ground which were flooded but believed not to be contaminated ("white 1");
- Areas of ground not subject to flooding ("white 2").

OIL POLLUTION: ACTIONS AND RECOMMENDATIONS

During the first days, when possible according to the site configuration, and more specifically when sufficiently thick layers of floating oil were contained, this oil was recovered by pumping, sometimes used in combination with skimmer heads. However, in more open areas, the high degree of spreading of the product at the water surface meant that sorbents were the only viable option. Sorbent booms were also laid as "sentry" devices, or near to points of pollution resurgence, or indeed in a protective capacity for certain sites. Very quickly, the quantity of sorbents required, and their installation, surveillance, renewal and treatment once oiled became an issue in itself. This came in addition to the problem of storing and processing the large quantities of litter and debris, whether oiled or not, generated by the flooding. Improvised storage areas were set up locally, sometimes in very restrictive conditions given the complex

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circumstances, in certain cases for instance without ground protection, creating a risk of secondary contamination.

When the water level dropped after a few days, some pollution was deposited as the water receded and needed a detailed field assessment to prepare clean up and monitoring recommendations. Cedre was involved (to define cleanup techniques to be implemented in homes and gardens), as well as the French geological survey office BRGM (for probing and sampling polluted soil) and the regional health agency ARS (for questions relating to health). These recommendations were not only used to conduct cleanup but also as supporting documentation to support the discussions initiated by the prefectures and affected peoples with insurance companies and to support insurance claims.

Photo 9 *Engine used oil in garden (source Cedre)*

Photo 10 *Used oil in a vegetable garden (source Cedre)*

Photo 11 *Oil level mark on a tree (source Cedre)*

Photo 12 *Vegetation burnt without trace of oil, possible effect of agrochemical products (source Cedre)*

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Photo 13 *Used engine oil in a garage after flood water recede (source Cedre)*

The main concerns were in connection with:

- the techniques and equipment for cleaning walls and other hard surfaces; according to the material and coating (paint, render, etc.);
- the clean-up of oiled objects, furniture, ornamental or fruit trees;
- whether or not fruit and vegetables grown in the gardens (in 2016 and the following years) would be fit for consumption, whether children should be allowed to play in the gardens, whether barbecues could be lit, etc.;
- the health risks posed by oiled basements;
- oily waste management.

A general framework memo, was rapidly generalised to all the areas affected.

- advice and key terms for use by the authorities, explaining the background to the pollution, the behaviour of the products involved and their impacts on soil and vegetation;
- recommendations for treating oiled gardens and plant debris, according to the type of site (lawn, trees, vegetable garden, etc.) and the extent of the pollution;
- recommendations for treating contaminated cellars.

The techniques recommended for gardens are similar to those used during the "botanical clean-up operations" implemented in oiled natural vegetated areas: scything, selective cutting, scraping, or even removal of a few centimeters of soil. In terms of the clean-up of hard surfaces, the emphasis was on the urgent need to contain, recover and treat washing effluents.

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The treatment of house walls of different material (stone walls, concrete, wood was left to specialised companies).

POST-POLLUTION MONITORING

MONITORING OF WATER QUALITY AND SEDIMENT

On request from the Prefect in charge of the coordination of actions for the Seine water-basin, a collegial approach was initiated in July 2016 under the monitoring of the Seine Normandy Water Agency (AESN). 25 representatives of the water basin partners and data producers concerned by the flood were involved (including state agencies, water management syndicates, private companies in charge of effluents treatment and water supply, scientists, research laboratories etc…), in order to assess its impact on water quality and aquatic environment, to capitalize on the feedback of crisis management, to identify gaps in data or data sharing and in flood control system that could be usefully addressed for the future.

This approach allowed sharing all the data on water quality that were collected during and after the event (this large dataset was based on 226 measuring stations).

The water quality was assessed according to the following parameters:

- Physico-chemical parameters (T, O_2, nutrients, COD, BOD) ;
- Main cations : Na, K, Ca, Mg ;
- Metals: Fe, Mn, Pb, Al, As, Ag, Cd, Cr, Cu, Ni, Zn;
- Organic contaminants: HAPs, PCBs, alkylphenol (AP), phthalates (PAE), polybrome diphenyl ethers (PBDE), perfluoroalkyl compounds;
- Pesticides: 6 pesticides (glyphosates, AMPA, dinoterbe, chlortoluron, atrazine, diuron) and 10 molecules (2,4 – D, boscalid, diflulenican, dimethenamid, ethofumesate, imidacloprid, metamitron, metazachlor, metolachlor, nicosulfuron);
- Medicines (paracetamol, Ibuprofen);
- Bacteriology (E. Coli).

A study of the fine sediments deposited when the water receded was undertaken as they provide an integrating signal of the entire event. These samples gave information on the particulate matter transported at the maximum of the flood, which was also the maximum of the suspended solids (SS) flow and thus of the associated contaminants. The use of a short-lived isotope, the ^{7}Be, only coming from the atmosphere via the rain, makes it possible to mark specifically soils, and to distinguish between the ancient origin or recent particulate matter collected from the flood deposits.

The selected families are metals, PAHs, PCBs, alkylphenols and perfluoroalkyl compounds. Most pesticides are mostly dissolved in rivers (but not necessarily in soils), so this family of contaminants has not been analysed on flood deposits.

RESULTS

In the water, the increase in TSS (total suspended matter) levels is noticeable at the time of the flood, but the levels recorded did not exceed 200 mg/L in any of the readings, which is not exceptional.

In conjunction with the flood peak, there is a peak of total organic carbon (TOC) during a few days, and in conjunction with increases in the TSS and TOC, oxygen concentrations have dropped as far as the estuary. It should be noted, however, that the oxygen level in waters remains perfectly compatible with aquatic life.

The magnitude of the flood, caused a runoff episode that resulted in very high nitrate values, but only over a few days. Levels of some pesticides, generally observed episodically in late spring, remained moderately high but were present for more than a month.

As expected during the periods of high flow that caused numerous networks overflows of wastewater and bypasses from sewage treatment plants, with significant quantities discharged directly into the natural environment without treatment, the level in fecal bacteria increased rapidly then slowly decrease to return to a concentration in the order of magnitude for bathing standard after a month and half.

The 2016 flood caused unusual and spectacular fish mortality due to the fact that lot fish became trapped in pockets of water during the receding of water and did not have access to the water (fish rescue operations has been attempted by fishing associations).

In sediment deposits, the levels of contamination by organic micropollutants were not as high as might have been feared given the flooding of urbanized areas and the resulting risks of contamination.

Levels of metal and organic contamination in the floodwaters have remained below the levels characteristic of the last few decades, confirming the progressive decontamination of the basin's watercourses, except for a few specific points probably linked to local sources.

For PAHs, the concentration was significantly higher than normal in the river basin the most affected by the flood.

CONCLUSION

The group underlined that, if the hydrocarbon contamination was only slightly higher than normal in the water and flood plains sediments, this pollution has particularly affected the inhabitants and territories affected by the event. Only some territories, such as the *Seine-et-Marne* and *Essonne* regions, have integrated this issue from the very beginning of the flooding, via the mobilisation of Cedre experts and fire brigade for detailed assessment and advise. Response preventive actions consisted in acting as quickly as possible while the water was still in place to limit the impacts on property, pollution of the soils and the risk of infiltration. Municipalities, that did not had the benefit of such an organization to deal with this pollution found themselves powerless to deal with the population demands.

The group concluded that the flood of 2016 presented as a violent event for the natural environment, increased by its late spring occurrence leading to high fish mortality, destruction, to impacts on the ongoing reproduction of fauna and flora, had at longer-term a positive effect for both wildlife and the hydromorphological functioning of the watercourses. The flood caused morphological changes, with the creation of pioneer environments (shallow waters, sandy islands) or the re-connection of certain wetlands usually poorly connected to the river.

Flood sediments deposits were noted as a remarkable integrative tool for assessing the contamination transported and deposited by the flood, given the contaminant content they carry, and the group concluded they should be systematised in case of floods.

As a lesson learnt, the participation in the working group of all the producers of data gave access to a large database and this was considered by the group as very positive. This exercise was carried out for the first time in the Seine basin and provided the group with a detailed and representative view of a large part of the basin.

The participants underlined the interest, should it be possible, to continue the data sharing process while at the same time putting in place a set of useful descriptors for the use of the data.

One possible action identified by the group would be to set up an internet platform to facilitate a rapid exchange of data to help crisis management.

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Oil spill in an estuary from a pipe leakage in a refinery

EVENT

On Sunday 16 March 2008, a pipe leakage caused a spill of an estimated 500 tons of intermediate fuel oil (IFO 380) during the loading of a vessel at Donges refinery, in the Loire estuary (Loire-Atlantique department, France). An amount of 200 tons of the oil spilt was estimated to have reached the estuary.

RESPONSE ORGANISATION

The company emergency plan and Crisis unit were activated as well as a Crisis unit at the Prefecture and an operational command post managed by fire-brigade. Spill experts were mobilised at once, Fast Oil Spill Team (Fost) from the oil company to set up containment and recovery equipment and Cedre for immediate surveys to establish contamination and first impact assessment.

The oil company managed the response under the control of the state ensured at first by the fire-brigade commander, then Cedre was responsible for drawing up recommendations in terms of shoreline clean-up techniques and monitoring the worksites.

On 17 March, a ban was introduced on sea fishing, by both professionals and amateurs, as well as on marine culture activities and the sale of aquaculture produce. The French Institute for Ocean Science (Ifremer) and the French Department of Health were put in charge of regularly sampling shellfish in order to monitor any possible contamination.

Deposits of oil were reported on the agricultural ground bordering the Loire river. Usually these pasturing grounds are used from April onwards. A grazing ban was introduced on nearly 4000 ha of meadows and toxicological experts from the Veterinary School of Nantes were involved in the monitoring in order to determine when the animals could return to their pastures after chemical analysis of grass and soil.

On 19 March, an environmental assessment unit, composed of experts from various backgrounds, was set up at the Préfecture to provide advice on response operations and set up scientific monitoring. The group included specialised agents from many different domains such as the protection of birds, veterinary medicine, maritime affairs and ecological organisations (National Office for Hunting and Wildlife, GIP Loire-Estuaire, Bretagne Vivante, LPO 44 (League for the Protection of Birds), Ifremer, the Botanic Conservatory of Brest, Nantes Veterinary School, representatives of national agencies in charge of Sanitary (DDASS), Equipment and Transport (DDE), Environment (DIREN), Maritime Affairs- and Cedre).

EXTENSION OF OIL

Over one night, oil slicks and sheen were spread on the water from 10 km upstream to the external part of the estuary and some oil was already ashore, mostly on the south bank of the estuary.

At the leakage point, the creek was heavily oiled (Photo 14) but during the first days, due to neap tides, mobile oil remained on water, on the lower part of the banks and mudflats (Photos 15, 16) while the upper part of the vegetated banks remained unoiled.

After few days, due to an increase in tide and in the river flow, a sudden spill-over occurred at high tide, and as a result, a large extension of contamination could be observed on banks. Oil penetrated into small creeks and overflowed spreading into wetlands and meadows where nearly 4 000 ha of meadow were submerged, 530 ha of which were heavily to moderately contaminated (Photos 17, 18).

Photo 14 *Location of the spill and view of the spill site just by the Loire estuary (Source Cedre)*

Photo 15 *Slick on water on the 17thof March (source Cedre)*

Photo 16 *At first, oil remained at the lower part of banks (source Cedre)*

Photo 17 *Due to tide increasing, large areas of wetlands were oiled (source Cedre)*

Photo 18 *Oil penetrated deep inside small creeks (source Cedre)*

A drifting model from Météo-France was run to forecast the drift of oil at sea and in fact, some oil tar balls and patches drifted southward and were scattered along the coastline reaching Oléron Island (around 200 km as the crow flies) 15 days after the spill.

Inside the estuary, trajectories simulations prepared in advance were included in the Contingency Plan of GPMNSN (Harbour of Nantes-Saint-Nazaire). In fact at this time, at that time, the available hydrodynamic model requires, 3 days before getting results. These simulations indicated a potential drift to 30 km upstream which was in fact the extreme distance from the leakage observed after some days (Fig. 20).

Fig. 20 *Maximum extension of the oil contamination in the estuary (source Cedre)*

RESPONSE TECHNIQUES

FIRST MEASURES: PROTECTION AND RECOVERY OF OIL ON WATER

In order to recover the pollutant at the external part of the estuary and at sea, the *Argonaute* Support, Assistance and Clean-up vessel (BSAD) from the French Navy was mobilised and equipped with a *Thomsea* trawl net. Inside the estuary smaller fishing boats equipped with small *Thomsea* trawls filled with loose sorbent were mobilised. There were only one or two access points to the banks for pumping by tanker trucks.

The Prefect of Loire Atlantique and the refinery mobilised their equipment to implement the installation of booms at various sensitive points in the estuary (creeks, industrial water intakes) and outside the estuary as for example at the entrance of the *Guérande* salt ponds.

In the estuary, strong flood currents, rapid drift, tidal amplitude, anchoring difficulties in natural muddy banks limited protection measures and floating oil recovery efficiency.

Photo 19 *Implementation of the Thomsea trawl net by a side arm on the Argonaute BSAD (source French Customs)*

Photo 20 *Trawling of the Thomsea by fishing vessels (source French Customs)*

Photo 21 *Craning a Thomsea trawl full of polluted floating reeds (source Thomsea)*

CLEANUP OPERATIONS ON LAND

At the maximum, 1000 peoples/day were involved during few days, and almost 700 during a month to cleanup the river banks and manage the oily waste. Civil Protection and fire service were mobilised at first and then progressively replaced by private service providers, 30 companies were involved, including rope access work specialists to cleanup port infrastructures. Cleanup operations lasted 3 months and the work effort amounted to 25,000 men/days.

Onshore, the techniques implemented were classic: manual collection of accumulations, high-pressure cleaning of infrastructures (quays, wharves, rockfill), pebble/rock washing sites with concrete mixers, etc.

Photo 22 *Oiled banks of blocks and rocks (source Cedre)*

Photo 23 *High pressure washing of rip rap (source Cedre)*

Photo 24 *High pressure washing in port basin by a rope work specialist (source Cedre)*

Large areas of vegetation were oiled and different types of vegetation impacted. Depending of the sensitivity of plants, contamination levels and accessibility, different clean-up techniques were applied: natural self cleanup (schorres and bulrush reed beds with very loose soil and light oiling), trapping of pollutant by net, manual cutting or mowing of heavily oiled reed beds using light equipment (such as brush cutters). In an area with sufficiently load-bearing soil, mechanical surface scraping using a mechanical shovel (which is normally banned in these types of habitats) was used, taking care to limit the impact on rhizomes. This delicate operation was carried out thanks to the shovel operator's know-how, which prevented the machine from sinking (in some places, the use of tread plates was necessary) and adjusted the scraping to the polluted layer (photos 25, 26, 27).

Photo 25 *Heavily oiled common reed (source Cedre)*

Photo 26 *River banks just after cutting of common reed and sediment surface scraping (source Cedre)*

Photo 27 *Complete regrowth of common reed after three months (source Cedre)*

LESSONS LEARNT

This pollution highlighted the difficulties and specificities of response in an estuarine environment due to strong and alternative currents, large tidal range, shallow waters, difficulties in accessing the banks, environmental sensitivity (wetlands and associated fauna), industrial sensitivity (water intakes), economic sensitivity (grazing, fishing, aquaculture, tourism).

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During the feedback phase, it was underlined that improvement could be made in term of:

- timeliness of drift model predictions transmission as the drifting of oil slicks in the estuary is fast and changing;
- improvement of dynamic recovery on water where the strong currents and the presence of shallow areas have limited the effectiveness of recovery operations. The lack of an anti-pollution boat adapted to the estuary (high motorisation, good manoeuvrability, flat bottom, etc.) was highlighted and the need to test new containment and recovery equipment more efficient than classical floating booms was underlined;
- Due to the difficulties of access, new tools like UAV (drone) could be useful to assess contamination extend and evolution along the banks and in marshes.

Photo 28 *Prototype of hovercraft for operations on mudflats and in shallow waters ("Hoverspill" CE project, 2009-2013) (source Cedre)*

Photo 29 *Trial in Loire estuary of a floating hydrocarbon containment and collection system for fast current-LMOS Sweeper system- (source Cedre)*

CONCLUSION

The analysis of hazmat incidents recorded worldwide for the past twenty years in Cedre database (from all available sources and specialized press), allowed to identify characteristics and sources of these incidents. The number of oil spills recorded is three time higher than chemical ones, while organic and mineral spills are scarce but huge in term of volume for mineral ones. In fact when an incident occurs in a mineral facility, the typical explanation of the large quantities involved is the breakage of the dam of basins containing sludge. For oil spills, the typical volume is 13 tons while it is 5 tons for chemicals.

The chemicals spills are characterised by the diversity of products and structures affected by incidents and the important number of poorly documented spill cases reported.

Sources of pollution from land-based installations are in the majority compared to pollution from vessels, resulting in frequent contamination of inland or estuarine waters.

The last 14 years incident records analysis showed that natural events are the cause of 11% of the spills, of which stormy rains and floods represent the majority of the cases reported.

The feedback on a large flood incident in northern France in 2014 underlined the diversity of widespread contamination sources and the difficulty to identify these sources. Hydrocarbons caused visible contamination requiring the implementation of clean-up operation, the chemical contamination and its duration have been sought and monitored through analyses of water and sediments deposited by the flooding. The study of flood sediment deposits was confirmed as a good integrative tool to assess the chemical contamination of the event.

This flood showed the importance of the rapid transmission and sharing of water quality monitoring results between the many stakeholders and managers carrying out partial or localised monitoring, and the group involved in the feedback process proposed to develop a web platform as a sharing tool.

The feedback on a medium oil spill in an estuary, underlined the usefulness of having a drift and behaviour model integrating river and sea. To be efficient, results must be made available and shared as quickly as possible among response stakholders, which again support the usefulness of a tool like a web platform as developed in HazRunoff project.

Containment and recovery on water are a difficult exercise in an estuary due to strong currents and stress the need for adapted equipment's and operators trained to these specific tools. The report "Analysis of response equipment well suited to transitional waters" (WP.4 task 4.2.3) in which containment and recovery equipment's adapted to fast currents are presented, underlines the efforts of oil spill response equipment manufacturers to take up the challenge.

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