CENTRE OF DOCUMENTATION, RESEARCH AND EXPERIMENTATION ON ACCIDENTAL WATER POLLUTION

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• Main oil spills worldwide

Deliberate crude oil release in the Amazon Basin (Puerto Asis, Columbia)

On 1st July 2014, near the municipality of Puerto Asis (department of Putumayo, Columbia), not far from the border between Columbia and Ecuador, an attack by guerillas on a road convoy composed of around twenty tanks (19 to 23 according to sources) resulted in a spill of between 4,000 and 5,600 barrels (approximately 650 to 900 m^3) of crude oil onto the road. This road runs alongside various watercourses in the Amazon Basin, tributaries to the Guamués River (which itself flows into the Putumayo River). Although the extent of the aquatic pollution was not officially confirmed, it nevertheless required response operations to be implemented, under the supervision of the Colombian army, which were completed a fortnight later.
The techniques deployed and the quantities recovered are not reported in our information sources. The army indicated that contamination of the Guamués River had been prevented.

Leak from a slop tank and pollution of the Guaracara River (Petrotrin refinery, Trinidad and Tobago)

On 29th July 2014, in the Republic of Trinidad and Tobago (Caribbean), a leak occurred from a slop tank at the Petrotrin refinery in Pointe-à-Pierre, resulting in the release of approximately 2,850 m^3 (according to the Environmental Management Authority) of a mixture of oil, water and sediment. Due to a failure of the retention area, almost 800 m^3 of this mixture is believed to have flowed off site and reached the Guaracara River, bordering the municipality of Marabella. Containment and pumping operations by vacuum trucks (belonging to Tiger Tanks Trinidad Limited and contracted by Petrotrin) are said to have resulted in the recovery of oil not only from within the site but also of 70% of the quantity released into the river, some 4 days after the incident, according to the operator.
Several inhabitants of Marabella were reported to have been admitted to hospital due to breathing difficulties, headaches, nausea, etc. The incident is believed to have been caused by the ageing condition of the tank (which was built in the 1960s) according to Petrotrin, and a defect in the construction of the retention berm.

Crude oil spill in a bayou (Mid Valley Pipeline, Caddo Parish, US)

On 13th October 2014, a crude oil spill occurred from a 20" land pipeline operated by Mid-Valley Pipeline Co., controlled by Sunoco Logistics, near Mooringsport (Caddo Parish, Louisiana, US). Three hours after having detected a drop in pressure in a section of line and having isolated this section and notified the National Response Center (NRC), the operator observed a leak on site. The crude oil released flowed into a watercourse (Miller Branch Creek), which forms Tete Bayou, a marsh which feeds into Caddo Lake.

The quantity spilt was initially estimated at 635 m^3 according to Sunoco, an estimation later increased to 715 m^3 when the line was restarted 13 days later. Given the emergency situation, the operator immediately initiated pumping operations by vacuum trucks at accessible points at the road edge and had containment booms deployed.

On the day after the incident, a Unified Command (UC) was set up to coordinate the response and included representatives of the relevant public agencies (US Environmental Protection Agency - US EPA, and the Louisiana State Police)[1] and the responsible party (Sunoco Logistics and its contractors[2]).

Initially, the US EPA and Sunoco implemented air quality monitoring. In the residential areas near to the spill site, which had been evacuated as a preventative measure, the concentrations of volatile organic compounds were below the detection limit. The inhabitants were therefore allowed to return to their homes. In the areas where clean-up operations were being carried out, the VOC concentrations called for appropriate PPE (safety goggles, respiratory protection masks, etc.) to be worn initially by responders.

Collection operations were difficult due to poor site access (heavily vegetated marshland) and the complex pathway taken by the floating oil. The following operations were implemented:

- Within the first few kilometres downstream of the spill:
    - at several accessible points on the banks, the crude oil floating on the watercourse

[1] With the support and cooperation of local, state and federal authorities: Louisiana Department of Environmental Quality, Caddo Parish Sheriff's Office, Louisiana Department of Wildlife and Fisheries, Louisiana Oil Spill Coordinators Office, Pipeline and Hazardous Materials Safety Administration, and the US Fish and Wildlife Service.

[2] Walker Hill Environmental, Conestoga Rovers & Associates, Oil Mop Inc., Garner Environmental Services, ISI Solutions and The Response Group (TRG).

was recovered by pumping using vacuum trucks, with or without a skimming head, during operations which lasted around ten days.

- o filter dams (bunds with pipes functioning by underflow) were built to optimise operations.
- o the liquid waste recovered was transferred in mobile containers to a temporary storage area.
- o in addition, the operator made an arrangement with a local landowner to use a private lake as a water reservoir to implement flooding operations in the watercourse upstream of the spill point, to help to rinse the banks and recover the oil via the filter dams.

*Containment by filter dams: bunds with pipes (**left**); Vacuum trucks for pumping floating accumulations between dams (**centre**); Concentrating the floating oil and directing it towards containment areas using hoses (**right**) (Source: US EPA)*

- On the second day of the response, dozens of additional responders were mobilised by Sunoco to manually collect oiled debris throughout the affected area.
- Meanwhile, in the marsh, floating booms, filter dams (oleophilic Oilshark textiles on stakes) were deployed in order to protect the banks and to restrict the spreading of the oil to Caddo Lake, a major priority[3]. These systems stopped the oil around 6 km downstream of the spill point (representing 16 km of shoreline in total), i.e. just under 1 km upstream of the lake.

*Containment/protection: in the creek, by floating booms, sorbent booms and oleophilic textiles on stakes (**left**); in the flooded area, by floating and sorbent booms (**centre**); at the mouth of Tete Bayou where it meets Caddo Lake, by rows of floating boom (with a drum skimmer between 2 sections of the 1st row) (**right**) (Source: US EPA)*

Oleophilic drum skimmer (Source: US EPA)

Between 14th and 28th October, the number of responders supplied by the service companies contracted by Sunoco to carry out the first response phase increased from around 60 to over 450. At this stage, the majority of the free oil had been recovered and the final clean-up of the watercourse and the bayou consisted mainly of the following operations:

- manual collection of residual floating pollution, using sorbents, and of oiled vegetation and litter.
- low pressure rinsing of pockets of oil on the banks.
- pumping of accumulations of crude oil at the water surface, often using small, selective oleophilic skimmers (drum or rope) appropriate for an environment littered with plant debris.

For these operations, conducted in difficult access areas with a low load-bearing capacity, small, light-weight, caterpillar track vehicles were used (Morooka rubber track carriers).

[3] This is one of the largest natural lakes in the southern United States.



*Collection using various types of sorbent (rolls, mats, pads) (**left**); localised rinsing of the banks using low pressure hoses (**centre**); pumping equipment deployed from small caterpillar track vehicles (**right**) (source: US EPA)*

Finally, the bunds with pipes built in the upstream pumping areas were removed and replaced with a single filter dam designed to recover the effluents generated by final rinsing operations in the watercourse (water release system at the spill source).

On 28th October, the US EPA reported the following figures: collection of around 475 m^3 of oil (of which 420 m^3 had already been recycled at Sunoco facilities), 38 m^3 of liquid waste (transferred to a suitable treatment site in Texas), 335 m^3 of oiled materials, and finally 630 m^3 of oiled soil (excavated from around the spill point).



*Manually collecting oiled sorbents (**left**); rope skimmer, pumping equipment and primary storage in IBC containers (+ ground protection using textiles (**centre**); 29/10/14: pipe for flooding/rinsing upstream in the watercourse (**right**) (Source: US EPA)*

In terms of impacts on wildlife, the federal agency published the following data in November 2014, indicating that the main impact was fish mortality:

					Died in facility	
	Captured	Cleaned	Released	DOA	Euth.	Other
Birds	1	1	1	2		
Mammals	1	1	1	4		
Reptiles	32	31	27	55		3
Fish	-	-	-	282		
Other	23	20	16	134	1	5
TOTAL	57	53	45	477	1	8

(Source: www.rrt6.org)

The damaged section of pipeline was replaced and tested, and was recommissioned on 26th October, under the supervision of the Pipeline and Hazardous Materials Safety Administration (PHMSA).

For further information:
http://www.rrt6.org/Uploads/Files/11-18-14%201510%20OSC%20Reports%20--%20Sunoco%20Logistics%20Spill.pdf
https://www.epaosc.org/site/site_profile.aspx?site_id=9578

Pipeline damage and oil pollution in a desert region (Eilat-Ashkelon pipeline, Israel)

On the evening of 3rd December 2014, a breach opened in the Eilat-Ashkelon (or Trans-Israel) pipeline[4] during maintenance operations, leading to a crude oil leak. A large share of the oil flowed in the wadi in the Arava desert (Be'er Ora region). The spill of medium crude oil (API=32, i.e. a density of approximately 0.865), which lasted around 2 hours, was initially estimated at 3,000 m^3, then later at 5,000 m^3 according to the Israeli Ministry of Environmental Protection (MoEP), which coordinated the emergency response.

Very rapidly the spill spread southwards, first along a road, then into the Arava desert, stretching 6 km by the next day.

View of the breach in the Eilat-Ashkelon pipeline (Source: MCED)

The affected area is ecologically sensitive: it includes Evrona Nature Reserve, the majority of which was fortunately spared, according to the Israel Nature and Parks Authority (INPA). Furthermore, it was feared that the oil would reach Eilat and the Gulf of Aqaba, around 20 km to the south. Ultimately the oil's spread was limited by the absence of heavy rainfall during the hours and days following the spill.

However to prevent the rain expected from causing the oil to spread further, containment and recovery operations were implemented by building dams downstream of the spill point, mobilising absorbing materials and pumping the oil from the pools and puddles formed on land or floating on the water flowing through the wadi.

Major contaminated soil excavation operations (where the oil had infiltrated into on average a 6 to 7 cm deep layer within the Evrona Nature Reserve) were also carried out. They began the day after the incident and were completed in early January 2015 with the removal of 30,000 m^3 of contaminated soil, transferred to a specially prepared site (Nimra landfill) to be treated by bioremediation.

Aerial view of the spill in the Arava desert (Evrona Reserve), following accidental damage to the Eilat-Ashkelon pipeline on 04/12/14 (Source: MoEP)

Approximately 2,000 m^3 of oil was recovered by pumping from the 210 identified pools of crude oil formed in natural depressions in the land[5].

*Floating oil (**left**); Oil spill in the wadi (**centre**); Fresh crude oil infiltrated into surface sediment (**right**) (Source: MoEP)*

On 7th December, with rain forecast within the following 48 hours (which was ultimately only light showers), the public operator Eilat Ashkelon Pipeline Company (EAPC) preventively set up two sorbent traps, composed of mop sorbents attached to ropes, designed to capture any oil flowing into the Kinet Canal[6] which connects to the port of Eilat. Meanwhile, on the 9th, the Marine and Coastal Environment Division (MCED/MoEP) deployed an offshore containment boom at the mouth of the canal in the port of Eilat.

[4] A 254 km-long pipeline, 1 m in diameter, built in 1957 and running between Ashkelon and Eilat-Red Sea (flow rate of 64,000 m^3/day from north to south, and 190,000 m^3/day from south to north), operated by the State-owned company EAPC (Eilat Ashkelon Pipeline Company).

[5] 30 pools of less than 50 litres, 180 with a volume of over 50 litres

[6] into which the waters of the catchment basin, including the oiled area, flow.

In late December 2014, the government earmarked a budget of 17 million shekels (€4M) for a programme to treat the residually contaminated soil as well as to restore injured wildlife populations (plan prepared by the MoEP and INPA).

*Laying mop sorbents in the Kinet Canal (**left**); boom set up on 9/12/14, in the port of Eilat (Gulf of Aqaba) (**right**) (source: MoEP)*

For further information:
http://www.sviva.gov.il/English/ResourcesandServices/NewsAndEvents/NewsAndMessageDover/Pages/2014/y%20December/Arava-Oil-Spill.aspx

• Main oil spills in France

Accidental overflow of oily water into the Etang de Berre (Provence refinery, Bouches-du-Rhône)

On 9th November 2014, exceptionally heavy rainfall[7] affected the south-east of France, causing the storm drains at the TOTAL refinery in Provence (La Mède, Châteauneuf-les-Martigues) to become saturated, as well as a storm basin and a storm tank (with a capacity of 30,000 m^3).

This flooding resulted in the waste water below the facility overflowing into the Mède canal. The outfall is located within an area surrounded by a permanent protection system composed of containment booms. The quantity of oil spilt was estimated at around 5m^3 by the operator.

The majority of the oil was contained in the section of canal protected by the permanent booms, however sheen was reported on the Etang de Berre lagoon, indicating that some of the oil had escaped through the riprap wall lining the canal. This was confirmed visually the following day by aerial surveys conducted using resources provided by the local fire brigade[8] (a drone deployed above the outfall). During the first few hours following the incident, the operator implemented emergency operations mobilising its own equipment and personnel, alongside those of FOST[9] and its subcontractors, in cooperation with the fire brigade (which also provided logistical support). These first measures included:

- the laying of sorbent booms, to line the containment booms prepositioned at the outfall and to concentrate various slicks which had been pushed up against infrastructures.
- the recovery of the contained oil by pumping (vacuum trucks, pumps, skimmers, etc.) or manually using sorbents.
- surveys to assess the spread of the oil within the Mède canal.

The day after the incident, oil was reported to have washed up on the shores of Châteauneuf-les-Martigues, at Jaï beach, located around 4 km east of the outfall. The Provence refinery called upon Cedre's assistance to carry out surveys of the pollution and provide technical advice on the necessary shoreline clean-up operations.

Two days after the incident, no more slicks were visible at the water surface in the Mède canal, except within the contained section (where pumping operations were still in progress). Sheen soon became clearly visible within this area and rapidly diminished. Infrastructures (walls, quays, pontoons, etc.) outside of the containment area were lightly oiled in a few places: a thin lining of oil was visible along the edge of a few concrete structures close to the outfall on the south bank and discontinuous accumulations were found at the foot of the wall along a 500 m stretch on the north bank[10].

[7] Around 160 mm in a few hours.
[8] Bouches-du-Rhône fire brigade (*Service Départemental d'Incendie et de Secours*)
[9] Fast Oil Spill Team
[10] Accumulations trapped by vegetation, possibly with floating debris, for which manual recovery was recommended and implemented.

On Jaï beach (Châteauneuf-les-Martigues), a continuous band of oil was seen along the high tide mark, more specifically along a 800 m stretch, where it formed a brownish, fluid, oily film. This 30 cm-wide film had infiltrated into a 3 to 4 cm-deep layer of surface sediment (biogenic coarse-grain sand and shell debris).

11/11/14: oily band along the western section of Jaï beach (Source: Cedre)

The recovery strategy defined for this light pollution which could not be collected without the risk of removing large quantities of sediment[11] lay in mixing/rinsing the oiled sand with low pressure water jets, using lances, while containing and recovering the remobilised oil using sorbents. A test, conducted in the presence of representatives of the operator and local councillors, validated this technique, which was then implemented by the company *Le Floch Dépollution*, contracted by TOTAL.

On another section of beach, composed of soft, heterogeneous sediment, the oil also formed an oily film, but which mainly covered the debris (shells, plant matter, seaweed, litter, etc.) deposited along the high tide mark.

Western section of Jaï beach: preliminary mixing test (low pressure lances) on oiled sediment: recovery, using sorbent booms, of the oil trapped in the sediment and remobilised by water jets (Source: Cedre)

Sheen could also be seen in places along the water's edge, as well as oil sporadically released from the contaminated debris along the high tide mark. Some small, thin deposits were sporadically trapped between the rocky boulders on the upper beach (which were otherwise unoiled).

The technical recommendations for this section of beach focused on the manual recovery of oiled debris along the high tide mark (shells, litter, driftwood, etc.), as it was liable to release the oil, and the recovery of the floating accumulations between the boulders using sorbents.

During the two following days, the residual oil was significantly reduced, due: to the low level of contamination, the type of oil (light, low persistence), the efficiency of the response as well as the site's self-cleaning potential (exposed to the very strong mistral wind during the night of 12th to 13th November).

Contamination of a hydroelectric dam with heavy fuel oil (Arc River, Maurienne valley, Savoy)

On 18th November 2014, *Electricité de France* (EDF) alerted the Savoy fire brigade[12] as to the presence of oil at the water surface near the Saint-Martin-de-la-Porte dam, in the Arc River (Maurienne valley). It rapidly became clear that a leak[13] of viscous heavy fuel oil had occurred upstream on the premises of the MT Technology foundry (Saint-Michel-de-Maurienne area). The quantity spilt was estimated at around 21 m^3, of which 11 m^3 was contained and recovered (by vacuum trucks) within the facility.

Traces of contamination were reported the following day up to around 40 km downstream, affecting the infrastructures of the EDF hydroelectric power system on the Arc (Maurienne valley) and Isère (Isère valley) rivers. From upstream to downstream this system is composed of: the Saint-Martin-de-la-Porte dam; the Hermillon underground plant supplied by a bypass channel (2 km) extended by an underground pipe (around 5 km); Longefan reservoir equipped with an overflow level regulation system, feeding into the Arc River, and supplying a 27 km-long underground tunnel through the Belledonne mountain range to the Flumet reservoir, located in Isère valley (Saint-Pierre-d'Allevard). This reservoir supplies the Cheylas hydroelectric power station which discharges the water into a final reservoir, before it flows into the Isère river.

The emergency measures taken by EDF consisted in temporarily closing the Saint-Martin-de-la-Porte dam, as well as the Longefan and Cheylas reservoirs (water discharge points into the Arc and Isère

[11] Especially as, according to the local authorities (in particular Châteauneuf-les-Martigues local council), this site suffers from a chronic issue of diminished biogenic sediment input and from beach erosion.

[12] *Service Départemental d'Incendie et de Secours de Savoie*

[13] whose cause is unknown to us.

rivers respectively) to reduce the spread of the oil in the natural environment.

To take over from the fire brigade, FOST and Cedre were rapidly mobilised to conduct surveys and provide technical recommendations relating to clean-up and spill response equipment deployment, operations which were carried out by the contractor Sita. The Isère authorities (Préfecture and DREAL services) supervised the clean-up operations and recommended implementing water quality analysis. Fishing and access to the banks were banned as a preventative measure by municipal orders.

Highly viscous deposits were mainly observed on the banks of the Arc River, between the leak point and the first EDF dam (oiling of overhanging rocks, stones and vegetation). Downstream, lighter contamination (50 to 80 cm high band) was observed on the concrete walls and the plastic lining on the banks of the bypass channel. Along the rest of the route, bank contamination was minimal (oily marks), and even absent from the Cheylas reservoir. With a similar decreasing intensity from upstream to downstream, flap gates, valves and spillways were also oiled.

Oiled stones on the banks of the Arc River (Source: Cedre)

On the water, highly viscous blackish accumulations could be seen, especially at the first dam, mixed with floating plant debris[14]; further downstream, the pollutant formed an oily brown film with an emulsified/foamy appearance[15] or sheen. We note that, given the large stretch of banks with potentially trapped oil, in addition to surveys conducted on foot and by boat, a drone (from the company *LAH Audiovisuel*) was deployed to survey the area.

Testing the resistance of a boom to optimise the flow rate: the boom is drawn into the spillway at a flow rate of 80 m³/s (Source: Cedre)

Furthermore, given the density of the fuel oil in upstream sectors, checks were carried out using sorbents attached to a ballasted rope to ensure that no sunken deposits were present in the first reservoir (Longefan).

The high flow rate in the Arc River meant that the protection/diversion systems could not be maintained close to the leak point. These systems were positioned directly upstream (containment booms with tidal compensation systems to allow for variations in the water level) and downstream (sorbent booms) of each structure. The flow rate was controlled at the base valves so as (i) not to affect the boom arrangements and (ii) to prevent the risks of oil entrainment (in particular by creating a vortex).

Recovery operations on the water were carried out by towing sorbent booms (simple or skirted) in various configurations (using 2 small boats, 1 boat and 1 operator on land, or 2 people on land in channelled sections), before pumping the oil gathered, possibly using a skimmer. In the last reservoir before the water is released into the Isère river, a settling/filtration system for the collected water was set up (involving 2 tank trailers and 2 separators in series with activated carbon filters).

On the banks, oiled debris was collected manually and the oiled walls and rocks were scraped from the bank or from boats.

Skimming and pumping contained oil from the banks, following collection by trawling (Source: Cedre)

Final clean-up of the walls was carried out manually, either using sorbent dipped in a washing agent, by rinsing or by pressure washing. Certain banks covered with a plastic liner were cleaned by low pressure washing with hot water.

[14] The screening tank retained very heavily oiled debris.

[15] Possible result of the oil being mixed by the turbines at the first plant.

*Low pressure rinsing of plastic liners with hot water (**left**); debris and fuel oil trapped in the screen of the Saint-Martin-de-la-Porte dam (**right**) (Source: Cedre)*

A few cubic metres of oiled stones were removed to be washed off-site.

The response lasted 3 weeks and was complicated by the fact that the oil had spread over a long distance and that the banks were often difficult to access. Furthermore, the spill occurred in a sensitive context due to operating constraints.

The impact on the environment was negligible: no aquatic wildlife mortality was reported and the water analyses performed upon request by DREAL did not indicate any contamination.

• Main spills of other substances worldwide

Retention basin failure and release of toxic waste water (Grupo México, Mexico)

On 7th August 2014, a spill occurred from a copper mining facility (Buenavista/Grupo México) in the Mexican state of Sonora, where defects in a holding pond caused 40,000 m^3 of waste water containing acids (used for copper extraction) and heavy metals to flow into the Bacanuchi and Sonora rivers, near the municipality of Cananea. Few details are provided in our information sources on the response operations implemented, however they are believed to have included the release of lime to attempt to neutralise the water. In addition, arsenic concentrations exceeding health thresholds were recorded following the incident, leaving 20,000 residents without drinking water.

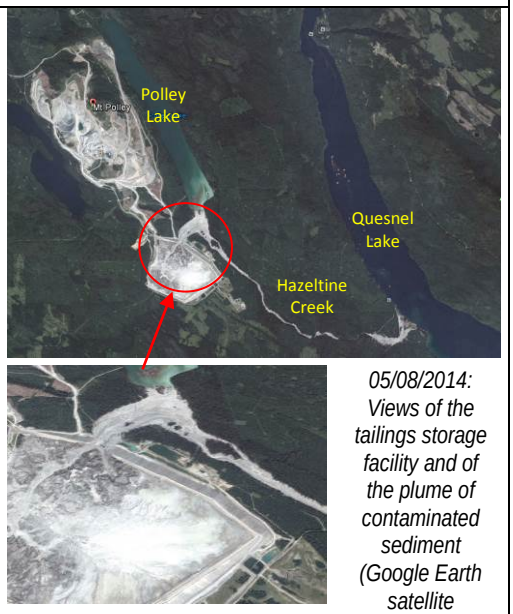
According to the press, quoting Sonora civil protection representatives, the spill was believed to be caused by the faulty design or construction of the relatively recent pond at fault. A second incident, of unknown cause but possibly linked to Hurricane Odile and the resulting flooding, occurred on the same site the following month, causing a spill of an undisclosed quantity of acidic waste water.

Spill from a tailings storage facility into mountain creeks (Imperial Metals Corp., Mount Polley, Canada)

On 4th August 2014, in the Cariboo region (British Columbia, Canada), a breach opened up in an embankment of a tailings storage facility, at the Mount Polley gold and copper mine (Imperial Metals Corporation).

This rupture led to the release of over 10 million m^3 of a mixture of water and sediment containing heavy metals (selenium, arsenic, lead, cadmium, etc.). Not only did the release (which lasted 4 days, until the facility was completely empty) directly affect Polley Lake, it rapidly spread downstream and was visible on Hazeltine Creek, Quesnel Lake and Cariboo Creek.

A local state of emergency was declared on 6th August by the Cariboo Regional District authorities, and a "Do not use order" was issued, banning the consumption and use of water in the impact zone. Monitoring programmes for water, sediment and fish contamination were commissioned by the Government of British Columbia.



05/08/2014: Views of the tailings storage facility and of the plume of contaminated sediment (Google Earth satellite images):

The drinking water ban was lifted on 9th August for residents of Likely, on the banks of Quesnel Lake, and downstream of the lake. It was lifted on 12th August for Quesnel Lake. This restriction was however maintained indefinitely for the areas where contaminated sediment had been deposited, including Polley Lake as well as Hazeltine Creek and the point at which it flows into Quesnel Lake. To support this decision:

- in the water, the concentrations of several metals continued to exceed chronic toxicity

thresholds.

- in the sediment, the levels of copper, iron, manganese, arsenic, silver, selenium and vanadium were high, however high levels of these compounds were already present prior to the incident according to the authorities (based on measurements from May 2014).
- fish flesh analysis revealed concentrations in excess of the guideline levels for human consumption for certain compounds, although they were similar to those measured prior to the incident, probably due to local geology.

In terms of pollution control, the British Columbia Ministry of Environment issued a Pollution Abatement Order to the company, in particular for Quesnel Lake, and called for an appropriate action plan. In this plan, the operator proposed to construct a berm, built in early September, to prevent the erosion and transport of contaminated sediment downstream by the currents.

Independent experts (geotechnicians) were appointed by the Government of British Columbia to carry out an investigation into the cause of the failure of the facility's embankment. These experts presented their conclusions in a final report published on 31st January 2015. They pointed to a combination of factors including the local geological environment (in particular a layer of fine sediment in the morainic subsoil), the slope and the gradual increase in the height of the facility's embankments (and therefore in the pressure exerted on the ground) over the 18-year period during which it was operated.

Ultimately little impact on the flora and fauna in Quesnel Lake was reported and downstream of this lake (in the watercourses downstream of Quesnel Lake only a temporary ban on Chinook salmon fishing was issued by Fisheries and Oceans Canada). For the affected upstream areas (Polley Lake, Hazeltine Creek), the comparison of the pre- and post-spill results indeed pointed to a chronic pollution issue. Although this was a major incident and led to a local state of emergency, the British Columbia authorities indicated that they did not consider this industrial incident to be an environmental disaster.

For further information:
https://www.mountpolleyreviewpanel.ca/final-report

• Review of significant spills having occurred worldwide in 2014

This analysis is based on an inventory of incidents in 2014 recorded by Cedre having led to a spill of over an estimated 10 tonnes, for which sufficient information was available. We remind readers that, for a certain number of incidents, the volumes spilt are not known or divulged by our information sources, although they clearly exceed the ten-tonne mark; these missing data and inaccuracies indubitably penalise the accuracy of the results presented below.

Spill sources

In 2014, 37 incidents followed by significant spills were identified in inland waters. By comparison with the corresponding data for 2004 and 2013 (median number = 40), 2014 appears to be in line with previous years.

This number of events however represents a total quantity of oil and other hazardous substances in excess of 10 million tonnes (Fig. 1). This estimation[16] is by far the highest recorded since 2004: with around 10,087,550 tonnes, it is roughly 3 orders of magnitude higher than the annual median for the period 2004-2013 (approximately 11,800 tonnes).

[16] Minimum estimation due to a lack of detailed data for several incidents.

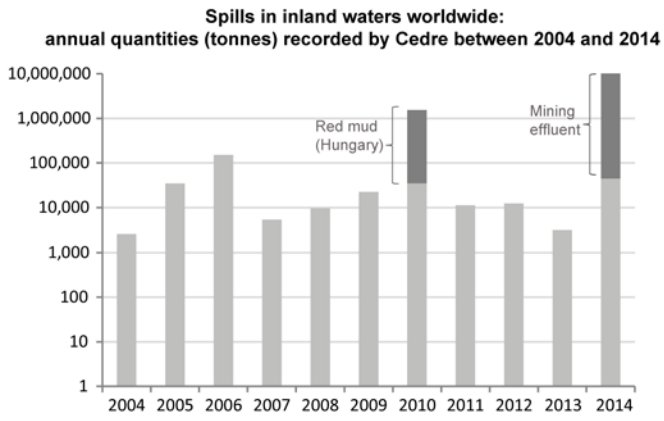


Figure 1

However we should be wary of jumping to conclusions about this exceptional total for 2014, as 99% of this sum can be attributed to just 2 events, which occurred in mining storage facilities in August (representing a combined total of over 10,040,000 tonnes of waste waters), one in Mexico[17] and the other in Canada[18].

The median volume of spills for the year shows that the spills in 2014 were distributed around a median value of approximately 50 tonnes. Furthermore, around a dozen cases, i.e. less than one third, reached or exceeded the hundred-tonne mark.

As in previous years, **pipelines** represented the most frequent source (24 %) of inland water pollution incidents, followed by overland transport in **tanks** (Fig. 2), representing a total of 14% of cases (divided between **tanker trucks** and **tank cars**, with respectively 11% and 3% of the number of spills).

On-land oil facilities were only at the origin of 10% of incidents, shared evenly between wells, refineries and **unspecified oil facilities**.

Various structures are then listed, each representing an equivalent share (around 8%): **power stations**, **mines** and small to medium-sized facilities (**various plants** and **agricultural facilities**). The other sources identified represented less than 5% of significant incidents for the year.

In terms of quantities, we note the overwhelming predominance (around 99%) of **mines** in the 2014 total (Figure 3), relating to the 2 incidents outlined above[19]. These mine-related incidents aside, the greatest quantities spilt were released from **power stations** and, to a lesser extent, from **land pipelines** (respectively 82% and 15% of the total, excluding mines).

Refineries were only other source to result in a release of several hundred tonnes. Given the patchy data identified, no accurate indication of the relative shares of other sources, most likely underestimated, can be given (Fig. 3).

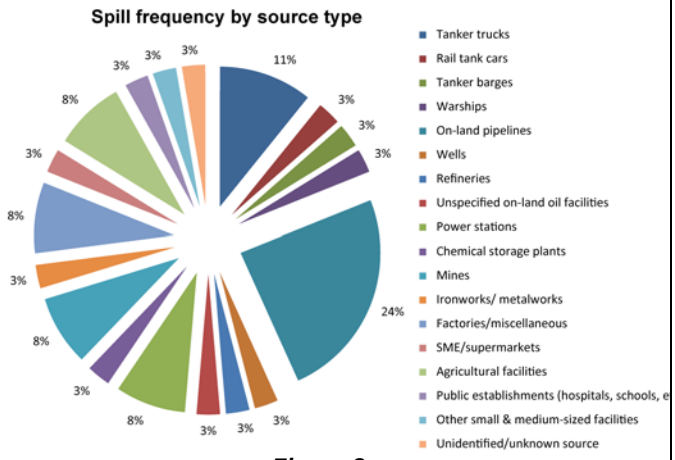


Figure 2

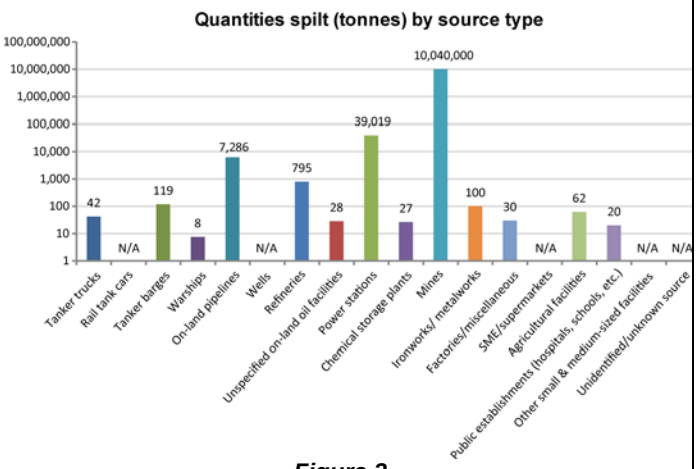


Figure 3

Types of substances spilt

Unlike previous years, the 2014 total is very largely dominated by releases of **waste waters**, in particular containing **mineral matter** from mining activities (10,040,000 tonnes of waste water mainly

[17] Contamination of the Bacanuchi and Sonora rivers, in the state of Sonora, with approximately 40,000 tonnes of mining waste waters containing acids and heavy metals.
[18] Contamination of the Quesnel River with 10 million m³ of waste water containing heavy metals, in British Columbia.
[19] See notes [17, 18].

containing heavy metals[20]) or industrial activities. The industrial category mainly refers to the 39,000 tonne-spill of slurry containing **combustion residues** (coal ash) from a storage reservoir at a power plant in the United States in February[21].

In the **oil** category, the greatest share (89% of oil) was **crude oil** (mainly **medium crudes**) due to incidents involving pipelines, the largest of which were in Peru[22], France[23], the United States[24], West Africa[25] and, above all, the Near East[26].

This was followed by **unknown/unspecified oil** (around 10% of oil products), ahead of **refined** products, whose share in the annual total is probably underestimated due to incomplete data (Fig. 4).

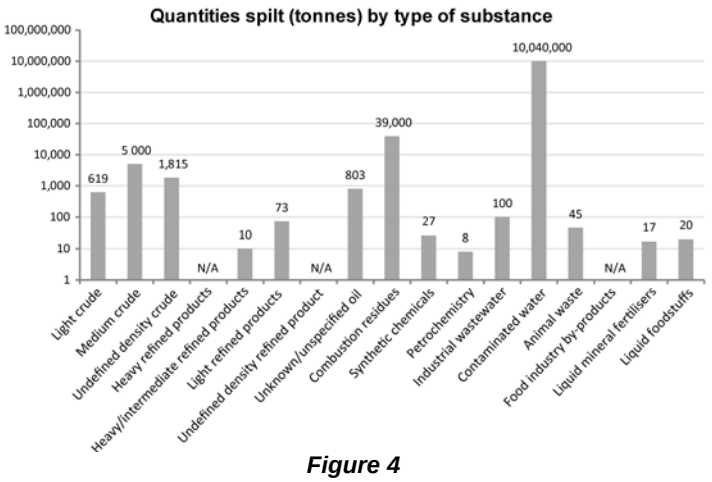


Figure 4

In 2014, the share of chemicals was once again far lower than that of oil.

Events

The most frequently reported incidents in 2014 were **breaches or ruptures in structures** (approximately 68%; Fig. 5):

- Most were due to a **loss of integrity** (41% of events) of structures. In half of cases, these structures were pipelines, while the rest were storage facilities (tanks, etc.) within various on-land oil facilities (industrial facilities, various plants, etc.). This category represented the second highest share of the annual total in terms of quantities (Fig. 6), mainly attributed to two spills of over one thousand tonnes, one of coal ash in the United States[27], the other of crude oil in Israel[28].
- **Overturning incidents** (especially overturning/derailment of road tankers

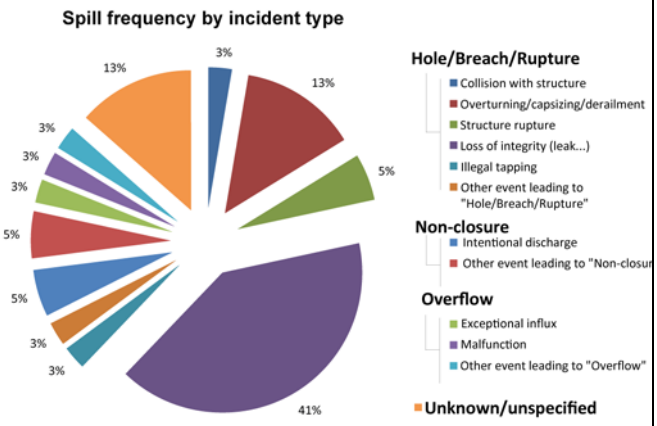


Figure 5

[20] But also acids; See note [17]
[21] Contamination of the Dan River (North Carolina, USA) following the incident within a former Duke Energy steam station; See LTEI n°22
[22] Contamination of a tributary of the Amazon River due to a spill from a Petroperu pipeline; See LTEI n°22.
[23] Spill of Ural crude oil in wetlands from the *Pipeline de l'Île-de-France*; See LTEI n°22.
[24] Contamination of Tete Bayou (Louisiana), following a leak from the Mid-Valley Pipeline (Sunoco Logistics); See above.
[25] Contamination of marshland and unspecified watercourses, within the states of Bayelsa and Rivers (Nigeria), from a breach in a Shell pipeline in November.
[26] Accidental damage to the Eilat-Ashkelon pipeline in Israel in December; See above.
[27] See LTML n°22
[28] See above

or rail tank cars) represented 13% of events (Fig. 5); they nevertheless represent a low share of the annual total (Fig. 6) due to the small scale of these spills.

- Despite a relatively low frequency (approx. 5%, Fig. 5), **structure ruptures** represented the greatest contribution to the annual total, due to the two previously mentioned tailings pond ruptures.

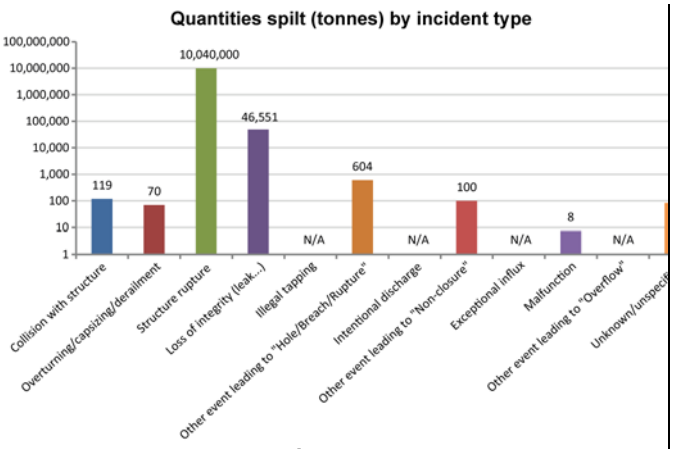


Figure 6

Aside from **unspecified events**, involved in 13% of cases listed, the other categories of events did not exceed 5% of cases (Fig. 5), with minor contributions.

Causes

Analysis of the frequencies of each cause shows that the cause was **unknown or unspecified** in 40% of cases listed (Fig. 7). This category also represented the largest share of the total balance in terms of quantities spilt (Fig. 8), due to one of the 2 incidents involving the rupture of tailings storage facility, which occurred for unspecified reasons.

Among the causes identified, we note the prevalence of **technical failures** (33%):

- Two thirds of such cases were related to the **defectiveness/dilapidation** of various facilities (Fig. 7), a cause ranked second in terms of the volume spilt (approx. 40,200 tonnes in total; Fig. 8).
- Despite their relatively low occurrence (5%), **facility failures (design/inadequacy)** virtually tied (approx. 40,800 tonnes) with the previous sub-category in terms of their share of the total volume spilt, mainly due to the rupture of the embankments of a tailings storage facility at a copper mine in Mexico.

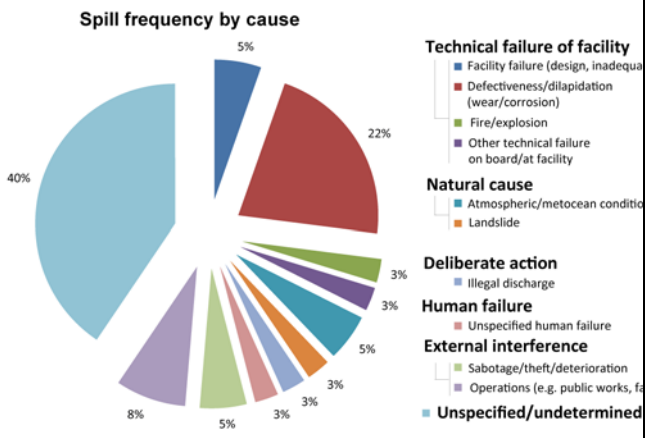


Figure 7

External interference was identified as the source of around 13% of events recorded (Fig. 7):

- The most frequent (8%) related to **maintenance work**, a cause which accounted for over 5,500 tonnes, mainly due to two cases of accidental damage to pipelines: the Eilat-Ashkelon pipeline in Israel (see above) and the far smaller spill from the *Pipeline Ile-de-France* in France (see LTEI n°22).

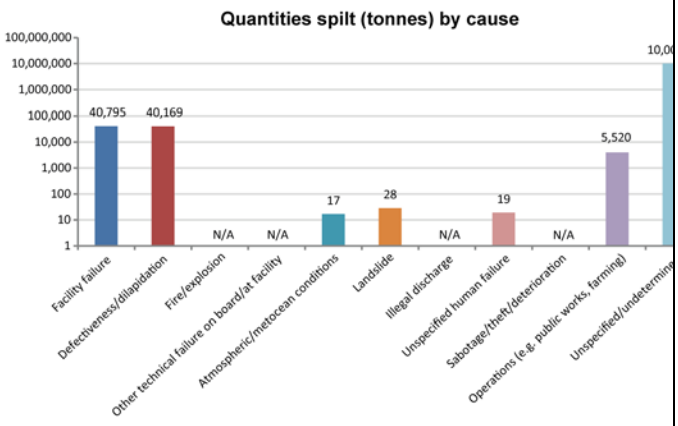


Figure 8

- Acts of **sabotage/terrorism/piracy/war** explain 5% of events in the external interference category. Such acts mainly concerned a pipeline in Nigeria and a convoy of tanker trucks in Columbia. While these incidents apparently led to spills of over 10 tonnes, the inaccuracy of the data available, common in the case of such incidents, means that their share in the annual total cannot be estimated (e.g. 5,000 barrels of oil spilt onto a road in the case of the attack on tanks in Columbia,

of which an unspecified quantity flowed into the neighbouring river).

The other causes identified showed relatively low frequencies (3 % at the most) (Fig. 7) and none weighed heavily in the 2014 balance in terms of quantities spilt (Fig. 8).

• Recovery

Small mechanical self-adjusting weir skimmers

Through recent projects in which Cedre has taken part, we tested various small skimmers using the standardised AFNOR procedure (NF T 71-500). These evaluations were the opportunity to determine the performances of each of the models which, although not new, are potentially of particular interest in specific contexts, notably for use at sites with limited accessibility (such as marshes, estuaries, streams, etc.), deployed from light platforms which will necessarily have a limited transport capacity (e.g. workboat, hovercraft, land vehicle, etc.)[29].

With this as a backdrop, trials were conducted on systems (skimmers + pumps) which met certain constraints, in particular size and weight requirements (less than 25 kg for skimmers), available hydraulic power less than or equal to 25 kW, and a low flow rate (<10 m^3/h) to enable them to be used together with the light-weight Turbylec separation system recently released on the market[30]. In this respect, the skimmers FOILEX Micro and DESMI Terrapin performed well on fluid to moderately viscous oil.

FOILEX Micro Skimmer

Weighing in at 17 kg and measuring 1.4 x 1.3 x 0.5 m (l x w x h), with a draught of 0.3 m, the FOILEX Micro skimmer features a central weir and a 3-pontoon flotation system designed to keep the skimmer stable in the moderately rough conditions for which it is intended (harbours or rivers). According to the manufacturer, the skimmer offers a maximum flow rate of 15 m^3/hour. Tested with the above-mentioned limits/constraints, this skimmer showed an average recovery rate between 3.5 and 9.5 m^3/hour for oils with a viscosity of 6,900 cSt and 1 cSt, respectively, and an average selectivity of between 42 and 94%.

FOILEX Micro skimmer (Source: Cedre)

For further information:
http://www.foilex.com/index.html

DESMI Terrapin

The DESMI Terrapin is also a self-adjusting weir skimmer and was originally designed for industrial applications (deployment in tanks, separators, etc.), hence it is light-weight (8.5 kg) and compact, with a diameter of 41 cm (initially to enable access to tanks through manholes, etc.).

With a draught of 0.34 m, it can be deployed in shallow waters, either free floating or suspended (according to whether the suction hose is connected to the underside or the top of the skimmer) and, given that it has no flotation frame, preferably in calm waters otherwise its selectivity may be compromised.

DESMI Terrapin skimmer suspended, with the suction hose attached to the top (Source: Cedre)

The manufacturer indicates a nameplate capacity of 10 m^3/hour. In our test conditions, the average recovery rates were between 2 and 8 m^3/hour, for oils with a viscosity between 6,900 cSt and 1 cSt, with a average selectivity of 35 to 87%.

For further information:
http://www.desmi.com/skimmers/terrapin.aspx

Ultimately, while the industrial scope of this type of skimmer leads, in a spill response context, to certain restrictions, partly relating to their dimensions, their compact format remains a potential advantage in specific contexts, in particular in the case of response in shallow waters and/or areas inaccessible to larger equipment, especially if additional equipment is deployed as part of the recovery chain to compensate for limitations (e.g. a small separator to overcome the decreasing selectivity due to increasing viscosity) and to reduce storage requirements.

[29] See details of the European project Hoverspill, aimed at developing a hovercraft (LTEI n°20).
[30] http://www.ylec-consultants.com/CMS/modules/dl/1451841076/TURBYLEC.pdf

A new type of belt skimmer: I^4 Innovation Slick Miner

The American manufacturer I^4 Innovation has developed a new type of belt skimmer featuring directional flights. This unique skimmer, dubbed the Slick Miner, is composed of an oleophilic Kevlar® belt (possibly filtrating, made of fine mesh) fitted with horizontal polypropylene brushes which act as flights.

Although this is a mechanical collection device, it nevertheless extends the range of belt skimmers (which mainly perform well on viscous products) to lighter products.

The oil recovered is then extracted by squeezing between a pair of drum pulleys, and is collected in a tank, from which it is removed by a pump.

The Slick Miner has been designed in two modules: the belt skimmer and the floating metal pontoon in the form of a catamaran to which the skimmer is attached. The two modules, each of a similar weight (45 kg), can be easily transported and rapidly assembled (4 clips). The skimmer can be used statically or dynamically, and can work in very shallow waters (10 cm). The frame and pontoon are made of aluminium and stainless steel.

The manufacturer offers various options with its standard 2.43 m-long belts, available in 3 widths (43, 58 and 74 cm), with the possibility of combining up to 4 belts to give a maximum length of nearly 5 m, and a choice of 2 inclines (30° and 45°).

For further information:
www.slickminer.com

• Litter

The Collector: a new litter collection prototype

In early December 2015, the Swiss foundation Race for Water, whose main preoccupation is protecting aquatic environments against plastic pollution, received the Collector, a boat designed to collect floating litter in inland waters, harbours or even in-shore areas.

The Collector at the NIL shipyard in Lorient (Source: www.entreprises.ouest-france.fr)

The prototype was developed by the recent Breton shipyard *Naval Industrie Lorientaise* (*NIL*). It is a catamaran with an aluminium hull, is 7.30 m long and 2.55 m wide, with a draught of only 50 cm.

Waste is collected by a conveyor belt, developed by *JC France Industrie* (the company which also markets the In'Clean 6.50, its own litter collection barge)[31]. This conveyor belt, fitted between the hulls, transports the objects collected towards an on-board storage capacity.

The date and place of delivery – Quai de Javel, Paris – were chosen to coincide with the Paris 2015 UN Climate Change Conference and thus help to raise awareness among industry and local authorities, agencies, water management bodies, etc. This first Collector has a diesel engine (2x 20 HP), but an electric version is due to be developed.

[31] http://jcfranceindustrie.fr/wp-content/uploads/2015/07/bateau-depollueur.pdf

• Sorbents

Low grade cotton as an efficient natural oleophilic sorbent

In the United States, the teams at Cotton Incorporated and 2 laboratories (the Nonwovens and Advanced Materials Laboratory and the Department of Mechanical Engineering) of Texas Tech University (Lubbock) have developed a sorbent from raw cotton fibres (unprocessed). This oil-absorbing material consists of low density, oleophilic and hydrophobic natural cotton batting, with an oil sorption capacity of 50.27 g/g according to laboratory testing (using the standardised procedure ASTM F 726-06), indicating an expected higher performance than that of many manufactured sorbents reported in the literature, according to the authors[32].

This result was part of an in-depth comparative study, by environmental scanning electron microscopy (ESEM), of the structure of mature and immature cotton fibres, which revealed that immature fibres have significantly higher adsorption and absorption properties (in particular by capillarity).

Furthermore, the use of optical microscopy to measure the specific surface area of longitudinal sections of mature and immature fibres (based on the Brunauer-Emmett-Teller (BET) method) led to greater understanding of the differences in sorption capacity between these types of fibres. The influence of the fibres' quality (fineness) was also examined and, based on the results obtained, the authors were able to quantify and rank the sorption capacity of cotton composed of fine, immature fibres compared to mature, coarser fibres.

The authors conclude that the carded cotton alone, without any sort of added binder, provides a fairly effective natural nonwoven product, especially as it uses cotton considered as low grade according to textile industry standards (but whose structure gives it a sorption capacity 7% higher than regular grade cotton).

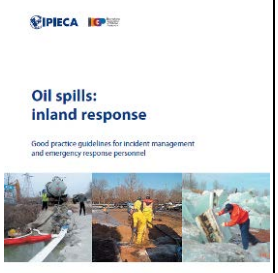
For further information:
Vinitkumar Singh, Sudheer Jinka, Kater Hake, Siva Parameswaran, Ronald J. Kendall, and Seshadri Ramkumar, 2014. *Novel Natural Sorbent for Oil Spill Cleanup*. Industrial Engineering and Chemistry Research, 53, 11954−11961. http://pubs.acs.org/doi/pdf/10.1021/ie5019436

• Response preparedness

Revision of IPIECA guidelines: inland response

Since early 2015, as part of the effort to revise the IPIECA Good Practice Guidelines, under JIP 12 of the OSR-JIP (Oil Spill Response-Joint Industry Project launched in 2011) led by IPIECA for the International Association of Oil & Gas Producers), new publications have been released, including guidelines on Inland Response.

This document covers freshwater rivers and streams, lakes and ponds, wetlands and estuarine water bodies. These environments are considered in relation to marine and shoreline spills, identifying similarities and highlighting unique issues pertinent to response, including the oil's expected behaviour and weathering, response techniques, any particular sensitivities, as well as the organisation of operations (responder safety, etc.).



For further information:
http://oilspillresponseproject.org/sites/default/files/uploads/Inland%20Response%20GPG.pdf

[32] By way of comparison, the sorption capacity of natural products, estimated in France using the AFNOR standard NF 90360, is generally less than 10.

• Research

ELDER: partnership between industry and Canadian authorities for pipeline leak detection

The Canadian companies Enbridge and TransCanada and the Province of Alberta decided to join forces in the field of research into pipeline leak detection, through the joint funding of a test system developed by their partner C-FER Technologies[33].

The resulting External Leak Detection Experimental Research (ELDER) test apparatus is a simulator within which pedological conditions close to those found at a given site (soil composition, temperature, etc.) can be recreated at meso-scale.

The development of this device was motivated by the poor feedback in terms of the real performance of detection equipment available on the market and, ultimately, of their efficiency.

The aim is to be able to test various oil pipeline leak detection technologies, based on the parameters set by the researcher: distributed temperature sensing systems (DTS), distributed acoustic sensing systems (DAS), oil sensor cables, oil or gas detectors...

The ELDER test apparatus
(Source: C-FER Technologies)

Furthermore, one of the expectations of this device was to provide the opportunity to assess and develop various real time information transmission systems (radio, satellite, etc.) to control centres.

From the outside, the simulator roughly resembles a container, and is 7 m long, 2.5 m wide and 2.5 m high. During the last quarter of 2014, C-FER Technologies installed the ELDER device (completed in 2013 after 2 years of development work) at a special facility, alongside other experimental devices devoted to other research issues of relevance to the oil industry and its developments (pressure in deepwater environments, pipeline testing, etc.).

For further information:
http://www.cfertech.com/

• Past spills

Remediation of contaminated soil: engineering ants in the spotlight

In August 2009, the rupture of a pipeline (see LTEI n°13) resulted in soil contamination within the Plaine de Crau nature reserve (Bouches-du-Rhône), a steppe region (known as coussoul), whose characteristic vegetation is almost unique in Western Europe.

In the area where 4,700 m^3 of crude oil was released, 200 fertilised harvester ants were implanted in the soil brought to replace the excavated contaminated soil (see LTEI n°18). The chosen species (*Messor barbarus*), selected for its ability to form large colonies, was expected to promote the regrowth of the original plants.

Three years on, almost 50% have survived and founded colonies. The workers continue relentlessly to bring seeds of around 150 different plant species which previously occupied this area of wild land across distances of 30 metres from the edge of unoiled areas. This ecological engineering operation – a world first led by the Mediterranean Institute of Biodiversity and Ecology (IMBE, CNRS-University of Marseille) as an experimental initiative – has proven to be very effective. The target of restoring the area's original vegetation cover – in particular the perennial grass *Brachypodium retusum* – has not yet been reached but progress is on track. This goal should be reached within a few years, which would have taken dozens of years without the ants.

For further information:
http://www.francetvinfo.fr/france/video-ces-fourmis-nettoyeuses-qui-aident-a-lutter-contre-la-pollution-d-hydrocarbure_609789.html

[33] Frontier Engineering Research, subsidiary of Alberta Innovates — Technology Futures, specialised in issues relating to the construction (design, materials) of structures, for offshore industrial developments in the Canadian Arctic.

Two years after the Lac-Mégantic disaster: progress report on the aquatic environment (Chaudière River)

On 27th November 2015, a report by experts contracted by the Quebec Ministry of sustainable development, environment and the fight against climate change (MDDELCC) suggests that localised sediment contamination remained in the Chaudière River, following the rail accident in Lac-Mégantic (Quebec, Canada) in July 2013[34].

As a reminder, in 2013, an estimated 100 m^3 of light crude oil (Bakken Crude) reached the Chaudière River, where around 43 m^3 of a water/oil mixture was contained using booms and recovered by pumping in various parts of the river.

While the extent and level of residual pollution have diminished on the whole compared to the immediate post-spill situation, the Ministry indicates that "concerning" levels of contamination remain at a few sites 2 years on, within the first 15 km of the affected stretch of river and in Lake Mégantic.

July 2013: aerial view of the pollution in the Chaudière River by Bakken Crude oil (Source: MDDELCC)

In terms of impacts on living organisms, the report indicates a high prevalence of external clinical signs (in particular the erosion of epidermal layers, or even deformation, of fins) suggesting sublethal effects, since 2014, within fish populations dwelling in these habitats. According to the MDDELCC, the fish suffering from these lesions did not show abnormal concentrations of contaminants in their flesh, and no restrictions on recreational fishing or the consumption of freshwater fish appeared necessary.

The results of toxicity tests conducted on various model species (benthic invertebrates[35] and fish larvae[36]) from the most contaminated sediments, together with an in situ exposure assessment, led to the identification of a persisting ecotoxicological risk for aquatic organisms due to sediment contamination levels which in places exceeded the acute effect reference value (VRA) for hydrocarbons (C10-C50) or the frequent effect concentration (CEF) for PAHs.

While the benthic communities at contaminated sites on the upper section of the Chaudière River appeared to differ significantly from those at uncontaminated or lightly contaminated sites, signs of restoration were nevertheless identified in 2014.

According to the report's conclusions, the Chaudière River monitoring programme will continue to run until 2017, when the expert committee will determine whether or not the programme should be further extended, based on the results obtained.

For further information:
http://www.mddelcc.gouv.qc.ca/lac-megantic/index.htm

[34] See LTEI n°21
[35] Survival and growth of larvae of the harlequin fly *Chironomus riparius* and the amphipod *Hyalella azteca*.
[36] Cyprinid *Pimephales promelas* and salmonid *Salmo trutta.*