LESSONS LEARNT
from industrial accidents

IMPEL Seminar
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Theme 1

Major fires

Major fires

Included in the category of major fires would be all blazes that generate damage beyond the specific unit or machine where the initial ignition occurred. This fact sheet will expose the human potential, social, environmental and economic consequences tied to these events.
Beyond the exact causes (malicious act, electrical malfunction, equipment defect, hot spot works, etc.), it is the combination of aggravating factors that actually assigns the qualifier "major" to a particular fire outbreak. A number of these aggravating factors are described in the present fact sheet.

The proportion of major fires occurring at classified facilities amounts to roughly 35% of all fires listed in the ARIA base.

Trend in accidents categorised as fire / major fire since 2008	***2008***	***2009***	***2010***	***2011***	***2012***	***2013***
Number of fires recorded in the ARIA base	*675*	*604*	*605*	*625*	*561*	*553*
Number of major fires (with entire building exposed to damage) recorded in the ARIA base	*190 (28%)*	*262 (43%)*	*227 (37%)*	*242 (39%)*	*205 (36%)*	*165 (30%)*

1. A cost for the company

1.1. Economic consequences

The average cost of damages ascribed to major fires in France equals approx. **€780,000** per accident, from a sample size of 338 accidents where this parameter has been recorded.
More than **26%** of these accidents resulted in economic consequences **greater than one million euros**. This cost threshold is reached by the loss of all or part of production capabilities during the fire, by destruction of the production building and machinery and by forced layoffs of the workforce.

1.2. A human and social cost for the company

The human and social consequences associated with major fires, out of a sample of 2,760 accidents compiled since 1994 and catalogued in the ARIA base, are as follows:

Human and social consequences	***Number of accidents recorded***	***%***
Loss of life	*32*	*1*
Serious injuries	*48*	*1*
Minor injuries	*508*	*18*
Forced layoffs	*756*	*27*
Population evacuated	*191*	*6*
Population confined	*41*	*1*
Safety perimeter installed	*409*	*14*

It should be noted that a number of accidents have required the evacuation or confinement of a segment of the affected population, and/or the installation of a safety perimeter outside the site boundary.

1.3. A lower cost for the natural environment

Only **4% of major fires**, from the sample of 2,760 accident records compiled since 1994 and catalogued in the ARIA base, had an **impact on local aquatic media (surface water or groundwater) or soil**. Extinction water is in large part confined on accident sites before being treated, thanks in particular to the existence of retention basins or storm drain system isolation valves.

Accidents generating an impact on the natural environment however are primarily due to the absence of appropriate fire extinction water recovery devices (shut-off valves, retentions, basins, etc.), including a loss of their sealant, inadequate design, poor maintenance or malfunction.

2. The aggravating factors associated with a "fire" type of accident

2.1. Building designs conducive to the spread of fire


Source : operator (ARR)

Several fires catalogued in the ARIA base involve buildings whose roofs, facades or installed equipments had been designed with combustible materials (e.g. combustible sandwich panels, polyurethane foam, wood structure and facade elements, and glass wool). These materials feed the fire and may complicate fire-fighter response, especially in light of the risks of structural collapse.

In addition to the choice of materials, aggravating design factors include:
- the absence of physical barriers or building compartmentalisation (e.g. fire walls) which would make it possible to contain or even halt entirely the spread of fire;
- the presence of machinery or amenities that promote fire propagation from one building to the next (conveyor system, ventilation ducts, openings in the fire doors).

ARIA 41482 - 24 December 2011 - 42 - SAINT-ETIENNE
Fire broke out around 4:35 pm in an industrial packaging company occupying 7,500 m² of floor space. The firm held in inventory 5,000 m³ of paper, cardboard and plastics, 32,000 m² in army archives storage (with 36 linear km of shelves) and a 2,500 m² mail sorting platform.
A thick plume of black smoke was visible over several kilometres. Nearly 120 fire-fighters had to be mobilised. All utility lines were closed and the entire district cordoned off. Around 1:30 am, the fire wall protecting the mail storage facility partially collapsed. First responders extinguished the last ignition sources on 28 Dec. The industrial packaging firm was completely destroyed. **The postal site was inoperable for just a short while as it had been well protected by the fire wall**. The army archive centre sustained damage.
The building had initially been equipped with sprinklers, but this installation was subsequently disassembled. After the accident, it was decided that a **30 m buffer space between the archive building and the warehouse would be introduced** during reconstruction. **Ceiling insulation** (flocking over a 5 m distance below the roof line) **was also to be reinforced. The building's facade protection turned out to be inappropriate given the exposed heat flux. The lack** of both fire protection and **compartmentalisation in one of the storage cells had in fact facilitated the spread of this fire**.

2.2. Delayed detection

The early detection of a fire influences the speed with which an effective response can be organised and deployed.
In several of the accidents catalogued in ARIA, it would appear that fire detection did not facilitate a quick response during the accident for the following reasons:
- **absence of fire detection**;
- presence of fire detection, but **lack of detectors installed at the site of the outbreak**;
- **inoperable detection device** due to:
  - deliberate decision by the facility operator to turn off the detection system, mainly for the purpose of proceeding with works or,
  - accidental detection system shutoff by, for example, lightning or **electrical outage**.

ARIA 25495 - 15 August 2003 - 38 - LE PONT-DE-CLAIX

Fire broke out in the nitrocellulose warehouse at a printing ink factory closed for annual holidays. **Given the absence of on-site personnel combined with a warehouse facility devoid of fire detection**, the alarm was sounded by neighbours. Fire-fighters responded quickly and had the blaze under control within 30 min. **The premises were completely destroyed : 3 walls had collapsed, and only the facade fitted with a metal access door was able to resist the fire.** The 4 tonnes of nitrocellulose stored in the warehouse were destroyed, as were the 6 barrels of substances previously opened and positioned in the 2 storage cells next to the warehouse. According to the factory operator, these products being consumed had been properly handled in their original plastic packaging placed in hermetically sealed barrels. Given the extreme heat recorded during the days preceding the accident and the absence of personnel for more than 5 consecutive days, evaporation of the nitrocellulose impregnation solvent caused its self-ignition. The Prefectural authorisation ordered constant monitoring of the storage zone to ensure that the solvent ratio did not dip below the normal concentration maintained at the time of acceptance.

2.3. Fire-fighting resources that are improperly designed or ill-suited to the type of risk

Several accidents listed in the ARIA base report a sudden drop in flow rate within fire extinction water networks during emergency response or, more commonly, **a depletion of water resources** available on-site to fight the blaze. As a result, the time spent by fire-fighters required to seek alternative water supplies (basins, rivers, tanker truck deliveries) winds up slowing the response.

Another aggravating factor in the event of fire pertains to the automatic extinction or smoke extraction systems connected to the general electric grid that become **inoperable upon shutting down the power supply**, whether involuntary or a deliberate step taken by the site operator or first responders.

The analysis of major fire accidents also suggests that the **fire protection and response system** implemented by the operator proves at times to be **ill-suited** to the risks inherent to site activities. Moreover, one of the measures adopted by operators following an accident involves conducting a risk analysis, with the aim of reconfiguring the site's protection and response system.

2.4. Vapour, dust or air extraction systems capable of fanning fires

The presence of an **operable extraction or ventilation system** at the time of a fire outbreak promotes spreading by acting as a conduit for ignited particles or by fanning the combustion, thus triggering the formation of flames.
This factor is definitely present in fires occurring in silos, woodworking shops, or within surface treatment facilities.

ARIA 32480 - 11 November 2006 - 21 - VILLERS-LES-POTS

Around 11 pm, at a 6,000 m² vegetable transformation and conservation plant, **fire broke out in the 200 m² room housing the ventilation and air conditioning equipment and spread into the suction ducts**. Heavy smoke was released in 2 adjacent buildings measuring 200 m² and 600 m², respectively. First responders cut off the electricity supply and **then isolated the ventilation and air circulation ducts**. They located the ignition source in the filtration room at the base of a chimney and proceeded by deploying 4 fire hoses to contain the blaze. The roof-mounted smoke removal system and sprinklers installed in the premises adjoining the plant's main boiler room were activated. **Fire-fighters perforated the ducts that had become abnormally hot**. Around 2:20 am, assisted by the Production Manager, **they located several other ignition sources, notably in the furnace extraction ducts and general exhaust chimney; they continued with their extinction efforts**. 30 min later, after surveying with a thermal imaging camera, no more hot spots were detected and responders left the premises. No victims were reported, but the site's production facilities were shut down for an indefinite period.

2.5. Vigilance in regions subject to wind disturbances

Wind is an aggravating factor regularly encountered in accident records. It stimulates the propagation of fire from one building or one facility to the next and fans flames. Wind also limits the efficiency of smoke exhaust outlets.

ARIA 33271 - 23 July 2007 - 26 - DONZERE
A violent fire broke out around 2:30 pm at a hazardous waste treatment centre. The blaze ignited in an outdoor stockpile of plastic rolls and then spread to the storage of paper-cardboard and adjacent pallets, before reaching the 5,500-m² materials sorting building. **Fanned by strong winds, the fire extended to nearby brush and destroyed 2 ha of vegetation bordering the neighbouring motorway**. On a positive note, a diesel tank in the vicinity was spared. Traffic on the motorway was slowed for a 4-hour period. No victims were reported, but the centre's 20 employees all had to be temporarily laid off.
This fire might have been caused by malicious act, but its quick spread had been facilitated by the short distance (less than 10 m) between the various storage sites and the main building.

3. Conclusion and recommendations

For companies, the costs of damage generated by a major fire are significant enough to motivate site operators to consider implementing a set of measures to combat this risk.

Analyses of major fires expose a large number of exacerbating factors. These factors must be identified in order for the operator to adapt site operations and as input into the risk analysis of their installations.

Risk analyses are typically conducted during project design via the generation of a safety report. Let's recall however the importance of repeating this exercise each time a new event arises in the life cycle of an installation. This is the basic task that allows identifying installation vulnerabilities and hence scheduling compensatory measures.

A few sample measures to keep in mind:

- compartmentalize the site units in order to avoid the propagation of hazardous phenomena;
- install fire protection devices (walls, check valves) or decoupling systems, notably in silos whenever the installation contains conveyor belts;
- adapt the type of fire-fighting equipment to the specific risks of the given industrial activity;
- ensure availability of the site's retention capacity for the extinction water volume, and adapt this capacity to subsequent changes in activity;
- set up a fire detection system that relies on its own energy supply and is relayed to secured alarms. The facility-wide management of these alarms must be governed by separate instructions and procedures;
- verify the presence, proper design and maintenance of extinction water recovery systems (shutoff valves, retention capacities, basins, etc.);
- become familiar with the types of materials introduced and the fire resistance of all buildings, structures and equipment (tanks, ducts) making up the facility.

Besides accounting for these aggravating factors in the facility design and life cycle, it is necessary to adopt the organisational measures that enable maintaining a high level of on-site safety (guidelines, procedures, training, choice of equipment, maintenance, control systems, etc.).

Fire on a stainless steel production line

23 December 2012

Gueugnon (Saône-et-Loire)

France

Metallurgical industry
Fire
Stripping
Fire detection
Fire extinguishing
Lockout
Maintenance
Hot spot
Backup power supply

THE FACILITIES INVOLVED

The site:

This metallurgical facility is located in the centre of the town of Gueugnon on a 34-ha site along the riverbank. The specific spot had been occupied by an activity dating as far back as 1724. The current company was founded at the end of 2010 out of the Group's desire to create a spinoff relying solely on its stainless steel alloy activities.

The Gueugnon site receives stainless steel rolls, proceeds with the lamination step and, in certain cases, finishing work. The plant itself employs a workforce of just over 800 people and comprises:

- chains dedicated to the annealing, shot blasting and stripping of the steel rolls;
- furnaces;
- production trains;
- annealing stations including rolling mills;
- finishing units (cut-outs, and sheet, disc or tight reel finishes).

The site was responsible for producing the hydrogen, nitrogen and oxygen required for the particular combustion conditions in the annealing furnaces thanks to an Air Liquide station set up on-site.

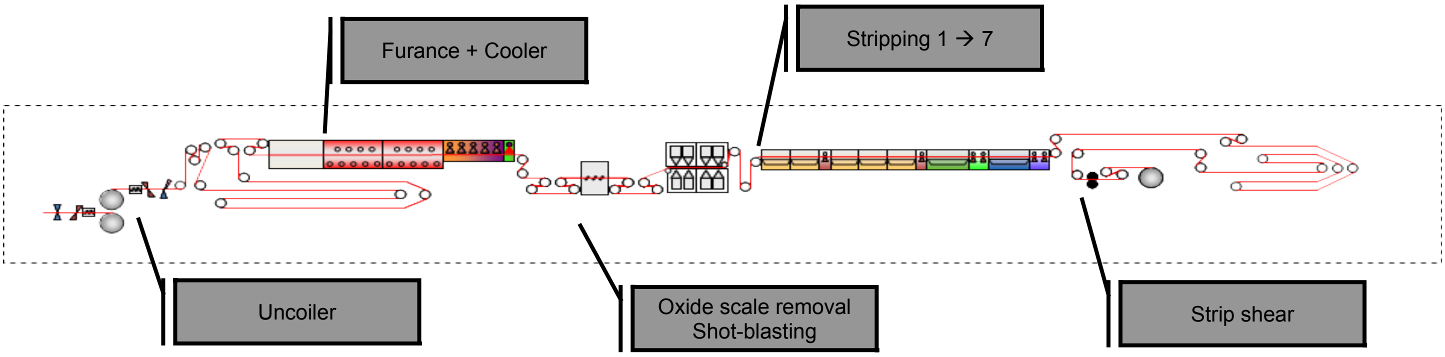
The stripping operation requires large amounts of hydrofluoric acid (HF) to be stored, which triggered the upper-tier SEVESO classification.

The specific unit involved:

The machinery placed on the new RD79 annealing-stripping line had been introduced during the production preparation phase lasting several weeks, but it had not yet been officially accepted.

The RD79 line is composed of:

- an input section with an uncoiler and an accumulator;
- a furnace + cooler section;
- a section for removing oxide scale and shot-blasting;
- a stripping section containing 7 polypropylene PPM tanks:
  - 5 hydrochloric acid tanks (numbered 1 through 5);
  - 1 hydrofluoric acid (HF) tank UG3P (No. 6);
  - 1 nitric acid tank (no. 7).
- an output section with an accumulator, a strip shear and a winding reel.



Moreover, the line contains ancillary technical premises, some of which are located on the mezzanine level, as well as electrical substations, tanks for collecting used acid liquor and mist washer jets.

Status of fire detection and protection devices on the RD79 line prior to the incident

• Existing detection and protection devices:

Since 16 October 2012, the RD79 line had been equipped with the following detection and protection features at the stripping station:

Smoke detectors:

– acid supply pumps on tanks 1 and 2;
– acid supply pumps on tanks 6 and 7;
– eastern stripping premises.

Flame detectors:

– stripping tanks 1 through 7.

Heat detectors:

– ducts and washers in unit named UGCO;
– ducts and washers on tanks 6 and 7.

Automated sprinkler system with a fuse head either underwater or by immersion:

– stripping tanks 3 through 6 (extinction by immersion);
– UGCO ducts and washers on tanks 3, 4 and 5 (extinction by immersion);
– washers on tanks 6 and 7 (extinction by immersion);
– Eastern sector stripping premises (extinction by sprinklers with a fuse head exposed to air).

Protection by means of a fire hose cabinet was operational at the entrance to the shot-blasting station on the Western wall.

All alarms were relayed into the line's input and output booth on an alarm annunciator, indicating the target zone. They were also relayed onto fire-fighters' beepers at the guard station, to the Operations and Maintenance Department and on the RD79 station manager's cordless phone.

• The following zone protections were on order or being installed:

Automatic extinction by immersion:

– stripping tanks 1 and 7;
– UGCO ducts and washers on tanks 1 and 2;
– ducts on tanks 6 and 7.

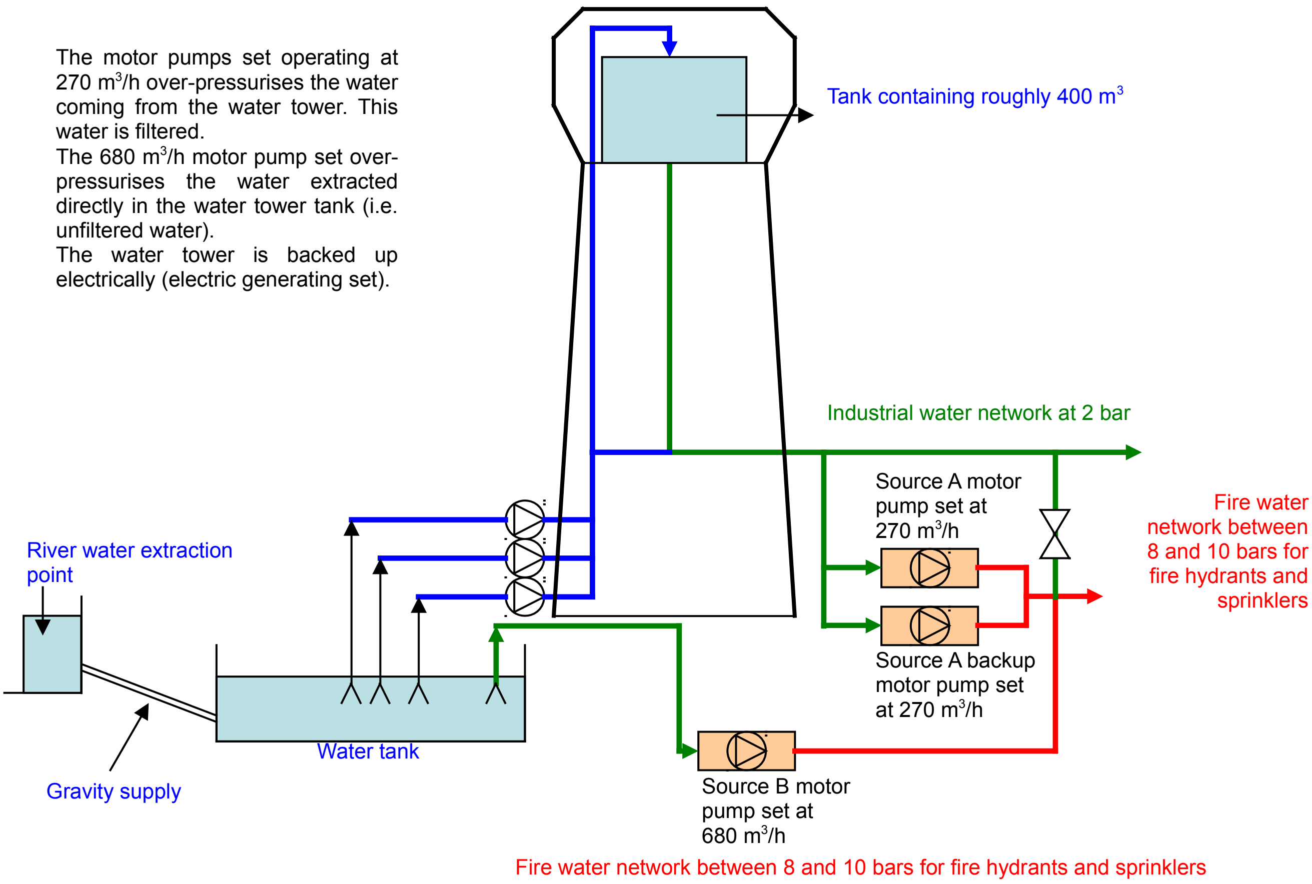
Planned extension of the Southern fire hose network after dismantling of the GD09 line.

Status of fire water supply facilities

In order to supply, as a priority, the fire water network and sprinkler type installations, the site had been equipped with:

– a source A motor pump set operating at 270 m^3/hour and its backup also running at 270 m^3/hour,
– a source B motor pump set operating at 680 m^3/hour.

The motor pumps set operating at 270 m³/h over-pressurises the water coming from the water tower. This water is filtered.
The 680 m³/h motor pump set over-pressurises the water extracted directly in the water tower tank (i.e. unfiltered water).
The water tower is backed up electrically (electric generating set).



The 680 m³/hour motor pump set directly draws water into the reserve located below the water tower. The 2 motor pumps running at 270 m³/hour were fed via the water tower and industrial water network. The combination of these sets of pumps supplied the sprinkler protection system as well as the site's 23 fire hydrants and a portion of the fire hose cabinets.

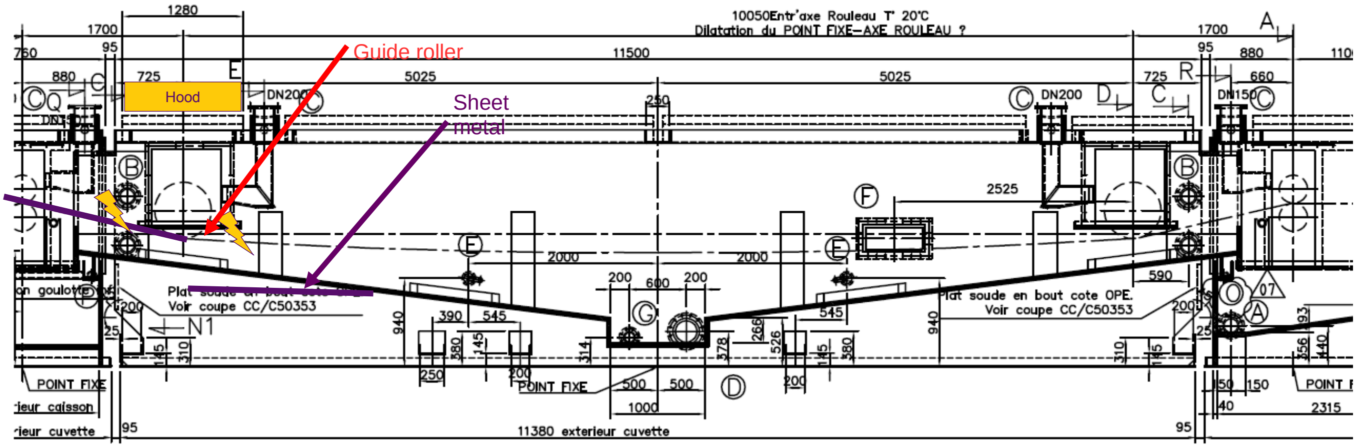
On the day the fire broke out, both A motor pump sets at 270 m³/hour had been operational, while the B motor pump set (680 m³/hour) was down subsequent to a major malfunction that had occurred in July 2012 while treatment was underway.

THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

The accident:

The 450 m long RD79 line is composed of several sheet metal treatment stations. This accident mainly affected the stripping installations. Investigations indicated that the most likely source of the ignition point was a welding operation taking place on a strip of sheet metal, which is typical in the process (occurring roughly once a month) and supervised by a specific procedure.

Less customary however was the fact that this operation had been carried out using a sheet metal strip guide roller, in a particularly narrow spot, which required the operator to wear both a head lamp and a mask.



The tests performed by the plant operator revealed that the material surrounding the roller, i.e. EPDM (ethylene propylene diene monomer) rubber, only required a small amount of energy to ignite. Placing a match in immediate proximity would cause it to slowly burn and be consumed entirely.

Upon completing the welding operation, the personnel began to reactivate the line in order to remove the belt without first reconnecting the fire detection system:

– gradual filling of stripping tanks, which had been drained in preparation of the welding operation;

– reactivation of the acid vapour exhaust hood.

Turning the hood back on most likely fanned the hot spot.

The flame was thus able to spread to the polypropylene lid on the closest stripping tank. The thicker tank walls liquefied and in turn also ignited.

These tests actually proved that the input of a high amount of energy was necessary to cause the polypropylene to burn.

Moreover, the line's compressed air pipes, made of a plastic material, melted while allowing a large quantity of air to escape, which undoubtedly contributed to fanning the fire.

Given the workshop's acidic atmosphere, much of the line's equipment had been designed and built using plastic: stripping tanks, honeycomb platform, acid vapour suction pipes, compressed air pipes, etc. These items, engulfed in the fire, generated a very significant combustible potential.

Chronology of the tripping of fire detection devices:

As a result of the RD79 line's fire detection lockout, the first information was conveyed by a sensor installed in a room adjacent to the RD79 line; known as UGCO. This room stored the buffer reserve of concentrated hydrofluoric acid used to supply the stripping tanks and moreover featured a smoke detector that transmitted an alarm to fire-fighters. The multiple and repeated detections then activated sprinkling within this room once the sprinkler heads had melted.

Next, the heat detectors present in the acid vapour suction duct relayed the information and triggered sprinkling inside this duct.

Lastly, the site's in-house fire-fighters manually activated sprinkling of the tanks.

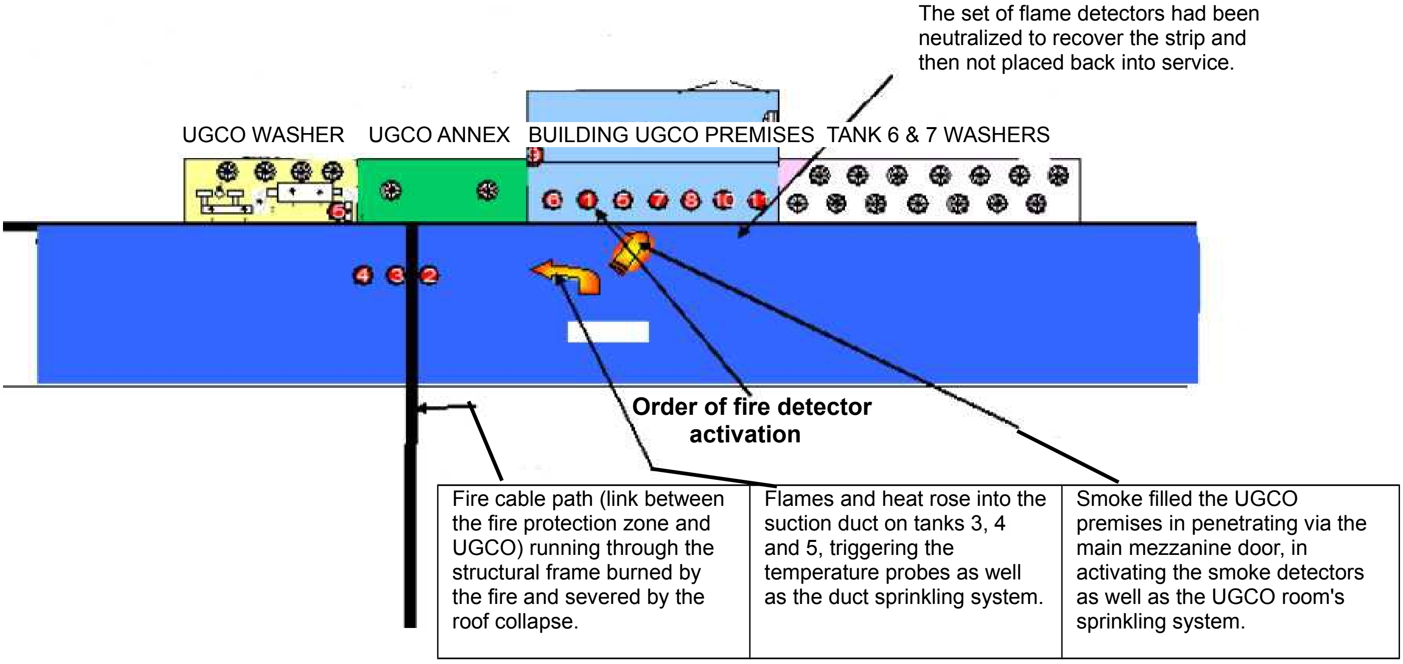
This violent fire could not be brought under control by the extinction resources at hand. Consequently, less than 30 minutes after onset of the blaze, the building roof partially collapsed, causing widespread electricity outages throughout the site, plunging the facility into total darkness.

Moreover, this collapse incapacitated the sprinkling network, thereby generating a tremendous water flow around the set of motor pumps. The 270 m^3/h set (source A) had to be placed in a secure operating mode. Manual intervention by site staff proved necessary to deploy the 270-m^3/h backup pump set.

Since source B was not operational, the automatic start-up function had been idled for several weeks.

Diagram depicting the chronological order of fire detection activation (source: operator)

1 - P73 smoke detector on the mezzanine level of the UGCO premises - fire-fighter's beeper alarm.
2-3-4-5 - UGCO duct temperature probes - sprinkler activation in the ducts of tanks 3, 4 and 5.
6 through 11 - smoke detectors on the mezzanine level and on the UGCO premises - sprinkler activation after melting of the sprinkler head on the mezzanine level.
Cut-off of the connection between the fire protection zone and the stripping detection after destruction of the cable path through the structural frame.
Manual tripping of the sprinkler system in the structural frame of tanks 3, 4 and 5, followed by roof collapse, causing the sprinkler network to fall.



Consequences of this accident:

The consequences of this fire were first and foremost physical. No injuries were reported.

The stripping baths, which had been undergoing filling with diluted acid, were drained by gravity flow by plant personnel just a few minutes after receiving information from the fire detection system:

- in the retention basins located under the RD79 line for tanks 1, 2, 6 and 7;
- in the remote tanks placed in the adjacent room for tanks 3, 4 and 5.

No environmental damage was thus recorded, given that no hazardous substances were directly at risk during the fire and moreover the extinction water could be confined on-site, primarily in the remote basin and then overflowing to the treatment plant. The retention basins on tanks 6 and 7, both made of polypropylene, melted during the fire. Nonetheless, it should be noted that these tanks only contained highly-diluted acids (less than 3% HF in tank 6 and less than 10% HNO_3 in tank 7).

The main physical consequences of this outbreak were:

- complete destruction of tanks 3 through 7 and their supporting structures;
- complete destruction of the recycling basins on tanks 6 and 7;
- destruction of the vapour extraction systems on tanks 3, 4 and 5 (UGCO washer);
- destruction of the building over a 120 m length;
- partial damage of the asbestos cement roof located on the eastern lean-to of building 37;
- damage to overhead travelling crane 114.

The presence of fire walls around the UGCO room helped protect the buffer tanks of concentrated hydrofluoric acid from the fire.

As an initial estimation, the amount of damage and operating losses rose to several tens of millions of euros.

External emergency rescue teams placed great emphasis on establishing efficient cooperation with on-site (fire-fighting) personnel throughout the crisis management and response period.


Source : operator (ARR)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European scale of industrial accidents:

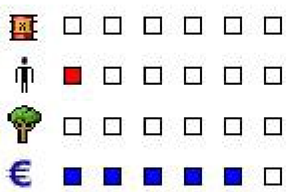
By applying the rating rules applicable to the 18 parameters of the scale officially adopted in February 1994 by the Member States' Competent Authority Committee for implementing the 'SEVESO' Directive on handling hazardous substances and in light of available information, this accident can be characterised by the four following indices:

Hazardous substances released

Human and social consequences

Environmental consequences

Economic consequences



The parameters composing these indices and their corresponding rating protocol are available from the following Website: http://www.aria.developpement-durable.gouv.fr

THE ORIGIN, CAUSES AND CIRCUMSTANCES OF THIS ACCIDENT

Upon studying the chronology of the facts underlying the fire outbreak and observing the subsequently damaged equipment (especially the rollers), the addition to the analyses and testing conducted on-site on the materials present at the time, the following scenario was determined to reflect the cause of this accident:

1/ During the welding operation, following spattering and/or the presence of heat, fire began to smoulder underneath the dipping roller, which was covered with an easily-flammable EPDM material that burned slowly with only limited smoke release. The technicians therefore did not notice this combustion.

2/ When capping the tanks with their lids, the active fire ventilation (the UGCO mist washer was still operable), the flames started to rise.

3/ Flames climbed to the tank lid and immediately heated it: since the lid was not as thick as the tank sidewalls, it began to melt (dripping plastic) and the ensuing liquid (highly flammable) stoked the fire and caused extremely hot flames. Tests conducted in-house after the blaze revealed that the temperature of these flames was capable of reaching 650 degrees celcius.

4/ The fire also spread by footbridges constituting the platform in front of the stripping tanks (plastic plates with an easily flammable honeycomb structure).

5/ The observation was also made that spraying water (using fire hoses) without any foam additive onto the liquid plastic only served to stoke the flames.

ACTIONS TAKEN

The operator implemented an action plan aimed to introduce several improvement measures in rebuilding the annealing-stripping line, as prescribed in a Prefectural decree issued in August 2013.

Design of the annealing-stripping line building:

- Installation of a roof composed of rock wool sandwich panels along with non-combustible lighting strips and including smoke venting, smoke exhaust equipment connected to the outside and structural openings to allow for natural ventilation;
- Protection of the hydrofluoric and nitric bath recycling tanks on those premises equipped with the REI120 fire walls separated from the main building;
- Protection of the mist washers in both the hydrochloric and hydrofluoric/nitric baths on premises equipped with the REI120 fire walls separated from the recycling tanks;
- Installation of a 100% retention basin for each recycling tank.

Choice of less combustible materials for the annealing-stripping line:

- Installation of a platform, in alignment with the stripping station, composed of class A2 materials (combustible, yet not flammable);
- Use of class A1 materials (non-combustible) for the platform, in front of each brushing machine, for the brushing machine box section and the mist suction ducts;
- Use of a roller lining made of relatively inflammable materials.

Networks and piping:

- Creation of a dedicated above-ground rack for the hydrofluoric acid pipes;
- Creation of another dedicated rack above the building roof line for both the hydrochloric acid and hydrogen peroxide pipes.

Water and foam supply:

- Increased supply of emulsifier, to better protect the stripping tanks and utility rooms;
- Installation of a separate structure independent of the sprinkling network support system.

Fire detection and protection:

- Relay of fire alarms into booths along the line as well as onto the portable device carried by line personnel;
- Installation of manual extinction system actuators in both the booths and the stripping zone;
- Implementation of an operational management procedure requiring restriction of the fire detection system;
- In each of the 7 stripping tanks and vapour suction ducts, installation of a double heat detection servo-controlled to:
  - shutoff of the suction device,
  - opening of the fire control valves prior to the washers,
  - triggering of CO_2 extinction from the bottom, the ducts and the washers.
- In the stripping zone, layout of detection zones, each equipped with 2 flame detectors, servo-controlled to:
  - extinction within the given zone,
  - cut-off of the vapour suction fans,
  - closure of check valves on the vapour washers,
  - tripping of the CO_2 extinction in the washer ducts.

- Installation of a double flame and smoke detection device automatically servo-controlled to the extinction (water + emulsifier) in the premises dedicated to hydrochloric, hydrofluoric and nitric stripping as well as in the washer room;
- The utility ducts and electrical rooms were equipped with a smoke detector priming the water supply to the automatic extinction system;
- In the water recycling room, installation of a fire detector automatically servo-controlled to the room's fire extinction resources (water-activated).

LESSONS LEARNT

Welding procedure:

The existing specific welding procedure was extremely tersely written. Its content was not commensurate with the importance of this delicate operation. Moreover, the existing hot spot working protocol was not being applied for this type of internal operation, even though the risk of hot spots was indeed a reality.

The welding location, in a particularly narrow and dark space, combined with the mandatory wearing of a mask owing to the acidic atmosphere undermined the chances of detecting the hot spot (by its glimmer, smoke release, etc.).

Acid vapour suction:

The lack of servo-control of acid vapour washer operations to fire detection was a factor contributing to this outbreak. Moreover, the design of acid vapour suction ducts using plastic material appears to be an ill-advised choice.

Along the same lines, the inability to control acid vapour extraction flow rates (with the destruction of some suction points having mechanically increased the suction flow rate of other points) fanned this fire. It should also be considered that the molten compressed air pipes strengthened the fire.

Fire detection lockout and lockout removal:

Given its sensitivity, the detection technology in place above the tanks (infrared) imposed their lockout in the case of welding tasks. It turned out that the line had been placed back into operations in order to release the sheet metal strip without removing the fire detection lockout first.

When questioned on this point, the plant operator indicated that in practice, employees wait to release the metal strip until the fire detection lockout has been removed, given the possibility of successive breakage (which would impose having to repeat the set of lockout procedure steps).

Fire protection resources:

The absence of fire protection zones on the platform, especially between the stripping tanks, seriously complicated the fire response. This observation was coupled with the apparent relative inefficiency of the sprinkling facility along the stripping line compared to a preventive action introduced perpendicular to the line.

The roof collapse, with a metal structural frame, caused several pipes to burst, including the sprinkling pipe.

Once melted, plastics exhibited the behaviour of flammable liquids, for which the use of water proves inefficient and may even tend to promote spreading of the fire due to the effects of spattering. This site had not been equipped with a sufficient quantity of emulsifier to successfully battle a fire outbreak of this type (i.e. like a "hydrocarbon" fire).

The automatic start-up of the 680 m^3/h motor pump set (source B) had been inoperable since July 2012 (even though several actions had been undertaken by the operator to repair the start-up mechanism during its idle period).

The site's pump wagon was incapacitated by the blaze. This equipment had neared the end of its useful life, but the operator had not allocated the budget for its replacement.

Management of the site's backup electricity supply:

The severing of an electrical cable, caused by the roof collapse, triggered a cut-off of the entire facility's electricity supply. Several electric generating sets were present on-site, but the most strategic elements on the circuit had not been backed up, namely:

– lighting;

– the TE02 treatment plant;

– the external emergency plan siren (even though this plan had not been activated during the accident).

Emergency plan:

The current internal emergency plan did not provide a satisfactory quantity of information relative to the water pollution management steps to be implemented in the event of such an incident.

This plan's recipients were only given an electronic version. The circulation of a print version would seem to be absolutely necessary.

Fire at a waste treatment plant covering nearly 18,000 m^2

2 November 2013

Fos-sur-Mer (Bouches-du-Rhône) France

Fire
Waste
Difficult emergency response
Operating loss
Delayed detection
Malicious act

THE FACILITIES INVOLVED

The site:

The site is a multi-stream solid waste treatment facility located on an isolated, 18-ha parcel within the Fos-sur-Mer business park, a site devoted to industrial and port activities. This plant began operations in 2010 and employs a workforce of some 150 people. It receives approximately 1,100 tonnes of garbage and debris per day generated by the 18 municipalities making up the Marseille-Provence Metropolitan area, including Marseille, with rail being the primary mode of transport.

Operations of the site's 3 units are subjected to authorisation, as per legislation regarding classified facilities:

- an initial unit for receiving and conducting a primary sorting of residual household waste (RHW), offering a capacity of 440,000 tonnes/year. This type of waste is sorted into three main families: recyclable materials, organic waste, and combustibles. Upon completion of this sorting step, the various products are respectively: warehoused prior to being recycled into new materials, or routed to either organic or energy recovery units;
- an organic recovery unit (ORU), authorised to treat a total of 111,000 tonnes of raw organic waste per year. This unit is composed of two rotating fermentation tubes (RFT), a secondary sorter, plus an anaerobic digestion unit containing two digesters and a composting station;
- an energy recovery unit (ERU), authorised to handle 360,000 tonnes of combustible waste per year. This third unit comprises two parallel lines equipped with combustion heat recovery furnaces and boilers, plus a turbine generator for electricity production, a smoke filtration system and a clinker ageing platform.

Overview of the fire that broke out at the Fos-sur-Mer municipal solid waste treatment plant

The specific unit involved:

On the night of 2 November 2013, fire broke out in the organic recovery unit located inside the facility's secondary sorting building. This unit was idle at the time. The blaze then quickly spread to the composting zone and ultimately to the primary sorting and unloading sector.

The energy recovery unit only sustained very slight damage.

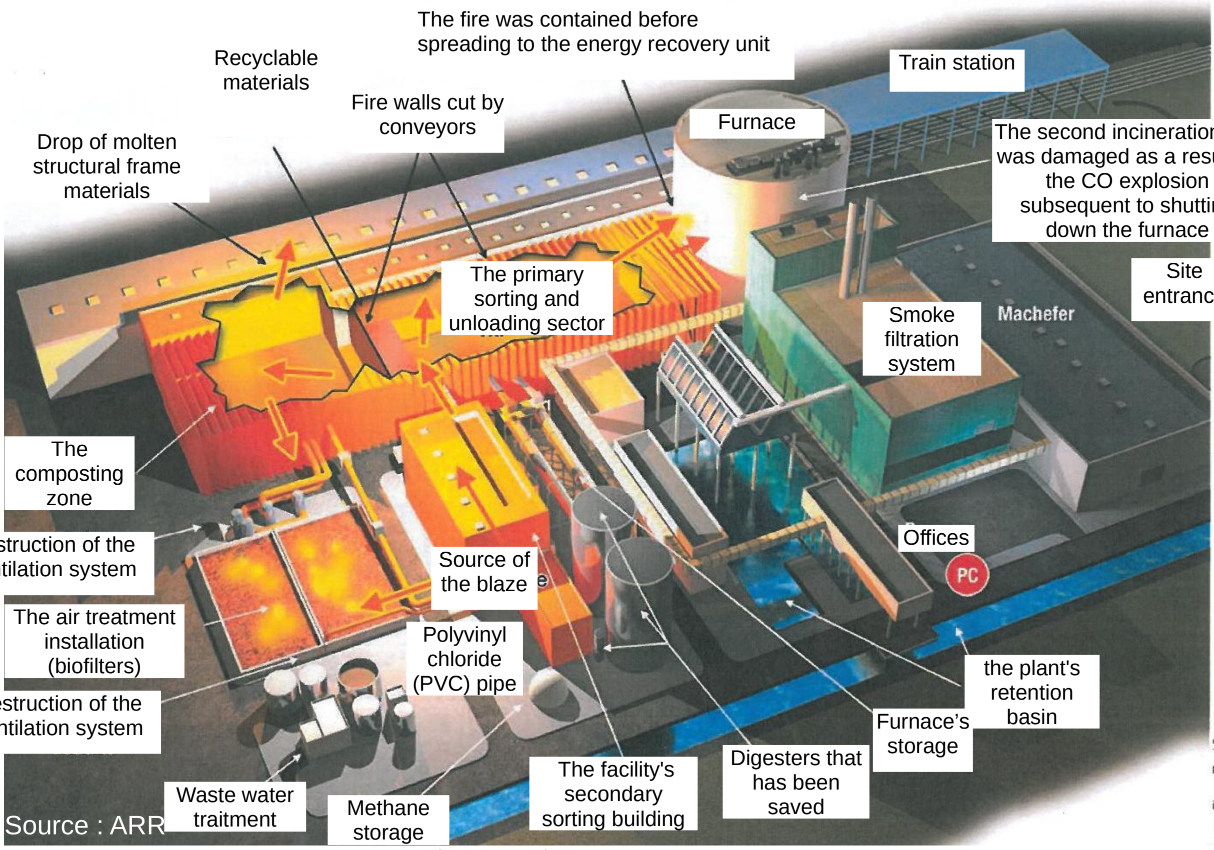


Diagram of how the fire spread inside the plant

THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

The accident:

At 2:38 am, the fire alarm in the electrical utility room of the secondary sorting building was tripped in the main control room.

At that same time, an employee located 100 m away in an adjacent building smelled smoke and discovered, in exiting that building, the 1,500-m^2 secondary sorting building in flames. He notified the site security office straight away.

First responders were immediately alerted by the control room of the energy recovery unit (ERU) .
Personnel of the ERU also showed up at the building and realised the infeasibility of an emergency response given the magnitude of the fire.

Informed of the situation around 2:45 am, the Director of Internal Operations (DIO) hurriedly arrived on-site and requested the internal emergency plan to be activated and mandatory protection deployed by fire-fighters for all installations within the biogas section of the plant, due to the risk of explosion.

Upon arriving at the scene around 3:05 am, external fire-fighters quickly attacked the blaze. Their response was initially intended to secure the most sensitive zones presenting either an explosion risk (i.e. anaerobic digesters, flexible biogas tanks) or a toxic risk (toxic product stockpiles including ammonia and methanol), in accordance with directives issued by the DIO.

Within just a few minutes, the flames fanned by a wind blowing from the south-south-east spread this outbreak to a 6,000-m^2 compost storage and ageing zone.

Primary sorting building ablaze

Incandescent cinders were suctioned by the fans, which were maintaining the buildings in a state of low pressure, causing the fire to spread to the air treatment and odour removal installations (biofilters laid out over 3,000 m²).

In less than an hour, the fire had engulfed the entire primary sorting zone. Then it advanced via conveyor belts crossing the fire walls as well as via the glued laminated timber frame atop these walls.

Fire-fighters took position to avoid the fire from spreading to the energy recovery unit.

Around 5:30 am, the sudden drop of molten structural frame materials from the primary sorting zone ignited two solid waste pits (covering a total of approx. 2,200 m^2 of surface area), thereby requiring fire-fighter intervention. The heart of the fire remained difficult to extinguish. After one attempt using water, fire-fighters launched an attack with foam.

Some 30 minutes later, a carbon monoxide explosion occurred on the lower part of one of the energy recovery unit furnaces, damaging the primary air intake duct. While remaining operable during the fire, this line had to be shut down when the control room was evacuated shortly after 3 am. The electricity cut-off stopped air inflow into the furnaces and combustion continued in an oxygen-depleted environment.

Given how the response was progressing, backup was requested. A major deployment of resources ensued: 140 emergency personnel and 40 vehicles battled the blaze under difficult conditions (due to the extent of protection required, coping with debris from partially collapsed structures, adverse weather conditions, a dense persistent smoke).

The fire extinction water was pumped into the plant's retention basin, whose operations were placed in a closed circuit in order to avoid effluent discharges outside the site boundary.

The fire was only brought under control in the evening. Smouldering outbreaks on the pits, the biofilter and the roof of the site's rail station were finally extinguished during the evening of 4 Nov. Two days later, the fire was officially considered totally extinguished. On-site monitoring was maintained through 8 Nov, i.e. 6 full days after the initial outbreak.

Consequences of this accident:

Human and social consequences

Despite the heavy quantity of smoke released, the facility's location was isolated from urbanised zones; moreover, with south-easterly winds sweeping the fallout of airborne particles towards the industrial park, the local population was not in any immediate danger.

As regards human impacts, no consequences were reported.

Environmental consequences

As of Saturday 2 November, the air quality regional agency's on-call manager announced that during the day, the concentrations of regulated pollutants in stations linked to the agency's network showed no differences from a typical day, and this finding held for all measured pollutants (nitrogen dioxide, sulphur dioxide, ozone and PM10 particulates).

An organisation specialised in managing emergency situations was contracted; samples of air, water (both groundwater and extinction water), soil and plants were conducted in the vicinity so as to determine whether the fire had caused an environmental impact (analytical parameters: PAH, phthalates, dioxins/furans, metals).
A marine environmental monitoring campaign was also undertaken.

Despite the lack of historical reference values for some parameters, the analyses performed did not reveal any **significant impact due to this fire on the environment**.

Physical and economic consequences

The waste unloading zone (for railcars) remained outside the fire perimeter, yet several beams running between the primary sorting/composting unit and the rail station were damaged by the fire. The station was reopened within the following weeks, subsequent to repair work and inspections. On-site waste deliveries partially resumed on 29 November 2013.

The down time of both pits 1 and 2, which were filled with drenched wastes during the fire-fighters' response, was initially estimated to last 4 months, corresponding to the period allocated to both repair the grabbing devices and evacuate leachates and wet waste to other treatment facilities.

To this day, the pits have been cleaned but remain unavailable for day-to-day operations. The damage sustained by the overhead track for grabbing devices (involving a misalignment problem) was in fact not detectable until a later time. The related works and inspections are scheduled for the upcoming months, and the pits should be placed back into service for day-to-day operations during the first part of 2015.

The primary and secondary sorting buildings as well as the composting platform were destroyed; these facilities accounted for over a third of all housed installations, for a total floor area around 18,000 m^2.


Source: SDIS - ARR


Source: SDIS - ARR

The dismantling of the primary sorting building and the "composting" building has been completed, while the secondary sorting building has been nearly entirely dismantled, except for a few pieces of machinery awaiting expert appraisal as per the insurer's request. The site rebuilding project application was officially filed on 17 September 2014.

The two anaerobic digesters and the energy recovery unit were completely spared, except for the second incineration line (primary air intake duct on one of the two furnaces), which was damaged as a result of the CO explosion subsequent to shutting down the furnace 3 hours prior. This line regained its functionality, following repairs, as of 25 December 2013. The first incineration line had been restored on 25 November 2013, roughly twenty days after the fire.

Since December 2013, the site has been operating at nearly 90% of its handling capacity, with just the energy recovery unit. Two years of works are required for all damaged installations to resume operations.

Physical damage and production losses amount to several tens of millions of euros.

European scale of industrial accidents:

By applying the rating rules applicable to the 18 parameters of the scale officially adopted in February 1994 by the Member States' Competent Authority Committee for implementing the 'SEVESO' Directive on handling hazardous substances and in light of available information, this accident can be characterised by the four following indices:

Hazardous substances released		□	□	□	□	□	□
Human and social consequences		□	□	□	□	□	□
Environmental consequences		□	□	□	□	□	□
Economic consequences	€	■	■	■	■	■	□

The parameters composing these indices and their rating methodology are available on the Web page: http://www.aria.developpement-durable.gouv.fr.

THE ORIGIN, CAUSES AND CIRCUMSTANCES OF THIS ACCIDENT

This fire broke out around the energy recovery unit, which is located in the "Secondary sorting" building dedicated to organic matter. This building was staffed by two 8-hour shifts.

Outside of working hours, i.e. at night after 9 pm, no personnel is assigned to the building, and all installations are emptied before the shift ends and cleaned of all organic matter. The building is thus free of any combustibles (organic matter), except for the structural components of the building itself (e.g. wall panels, conveyor belts).

During the preceding days, no maintenance work had been singled out as capable of causing a fire outbreak inside this building.

As for weather conditions, no thunderstorm activity had occurred within the zone. On the other hand, the presence of a south-south-easterly wind fanned and helped spread this blaze quickly.

In light of these on-site elements and resources (lack of video monitoring within the zone, failure on the part of the watchman or employees to observe any anomaly before 2:40 am), no physical cause responsible for the hot spot could be identified by the court-appointed expert.

In his report's conclusions, the insurance company expert excluded any accidental cause behind the ignition of this fire and moreover considered that the only plausible explanation was arson. The plant operator filed a complaint.

An analysis of how quickly the fire spread, however, revealed several issues mentioned during post-fire experience feedback:

- Despite the presence of some 200 smoke or flame detectors laid out across the buildings and electrical utility rooms, none was at the specific zone of the fire outbreak when it occurred. The absence of a means of detection in this building had been noted by the operator: the fact that this sector was assigned a permanent human presence during operations of the secondary sorting building led to the decision to merely install manual tripping devices, in recognising that at night, no activity is taking place inside the building and moreover the sorting line is systematically emptied and cleaned, thus leaving no combustible organic matter residue. Unfortunately, this absence of detection capability enabled the fire to generate momentum before being detected by a sensor located in one of the building's electrical utility rooms;
- Presence of many combustibles in the building materials (polycarbonate facade, wooden structural frames, rubber belt strips, etc.);
- Neutralised effect of the fire walls. As a matter of fact, some fire walls were cut by conveyors (with only some being equipped with water curtains), which were then covered by wooden structural members;
- Inability to turn off building ventilation despite the detection of fire. The incandescent particles suctioned into the air ducts connecting the various buildings spread this fire towards the air treatment facility (biofilters). The heat contained in these ducts then caused them to ignite;
- The smoke removal surface area and the compartmentalisation were deemed inadequate around the pits;
- Water availability needs to be optimised in the fire water supply basins, in spite of a sufficient water volume.

ACTIONS TAKEN

As regards post-accident management, a Prefectural emergency order was issued on 3 November 2013 by the regional Prefect, based on a proposal submitted by the Regional Directorate for the Environment, Development and Housing imposing that the operator implement all provisions to make it possible to conduct additional investigations to assess the accident's potential environmental impacts.

Start-up conditions were also established by way of an additional Prefectural decree, signed on 22 November 2013 and inspired from Classified Facilities inspectors' proposals.
As regards the energy recovery unit, which only sustained slight damage, the operator had to certify the unit's integrity and effective operations of all machinery therein, in addition to the various safety equipment, such as fire detection and protection networks (fire hose cabinet, hoses and water canons, etc.), prior to restart.

Given the emergency of the situation, inspection authorities granted the operator, as an exceptional measure, the right to incinerate residual municipal solid waste without any initial primary sorting. This degraded mode of operations was permitted while awaiting reconstruction of all site installations, in accordance with the Prefectural authorisation. It should be noted that nearly all of France's residual household waste incineration facilities operate without primary waste sorting. Yet a study was still requested within 3 months on the implementation of a temporary primary sorting solution either on-site or contracted to an off-site installation. At present, a temporary primary sorting station is being set up on-site.

In addition, to accommodate incoming waste, only one of the three pits is available to conduct ordinary operations, but this one had not been equipped to handle wastes received by train. While waiting for this system to come online, Classified Facilities inspectors issued a waiver allowing the operator to unload waste arriving by oversized lorries. This situation lasted 3 weeks and resulted in a temporary traffic of 15 lorries/day, for an incoming daily load of 325 tonnes of wastes.

The operator was asked to explain the conditions to adopt in order to manage the joint activity created by restarting the ERU and launching reconstruction works on the destroyed units.

A report verifying fire hydrant flow rates was also requested, so as to determine compliance with the Prefectural order. This verification exercise was conducted by a third-party.

For those installations treating gaseous effluents, a verification of the efficiency of filters used to treat smoke plus another verification of discharge monitoring device calibration had to be carried out. A higher frequency of inspections of airborne discharges by a third party was imposed upon the operator within the first 3 months following ERU restart.
The operator was also requested to specify conditions for managing odours (water, unloading building, pits) in addition to both rainwater and fire extinction water stored in the site's retention basins.

During the site reconstruction phase, the enhanced prevention and fire-fighting capacities, in terms of human, technical and organisational resources, were prescribed by another Prefectural order adopted in October 2014, consisting of:

– increasing the number of fire detectors in order to quickly notify the operator of any fire outbreak, including around the conveyor belts and air suction ducts running between the buildings;
– servo-controlling the conveyor belt shutdown to the fire detection system;
– installing cut-off valves on the air suction ducts between buildings, whereby the closing mechanism is servo-controlled to the fire detection system;
– ensuring the permanent presence of a backup response team equipped with Self-Breathing Apparatus;
– adding a mixed 2,000 l/min water/foam cannon with a hitch for towing and two 1,000-litre tanks of emulsifier;
– setting up additional fire water outlets in the reserve water supply, and improving the re-supply of these facilities (electric generating set / booster pump);
– doubling the number of water cannons installed around waste pit no. 3 as well as the number of smoke removal hatches located above the three pits;
– pressurising the control and instrumentation room in order to permanently maintain it free of smoke in the event the pit ignites;
– updating the internal emergency plan and proceeding with its test in conjunction with the local Fire Services.

The operator also added extra security at the installation access points beginning on 8 September 2014, by means of creating new "safety agent" positions. With this new organisational set-up, the site has an around-the-clock presence with two employees assigned these enhanced security functions (one from the hired security firm, the other a designated security agent).

The density of cameras mounted has also been raised and another line of protection added to the plant's fence around sensitive zones, such as the railway section of the site or the watchman's station.

Given the previous elements, no criminal charges were brought or administrative injunctions issued by Classified Facilities inspectors.

LESSONS LEARNT

The main lessons that can be drawn from this type of fire within a municipal solid waste treatment plant are as follows:

✔ The importance of fire detection with a relay to the control room, in zones where the particular wastes are present, but also near the conveyors and suction ducts, in order to respond as quickly as possible;

✔ Reactivity required, accident knowledge, deployment of an emergency response;

✔ The preliminary study proves vital to establishing construction provisions for a building and avoiding and/or limiting all the ways a fire can spread: fire walls exceeding roof height, institution of compensatory measures in the event these walls are crossed by conveyor-type equipment so as to ensure continuity in the degree of fire protection, choice of non-combustible construction materials, placement of fire cut-off valves within the air extraction ducts;

✔ The importance of the right design for fire-fighting resources, whether they are human, technical or organisational;

✔ Mandatory monitoring of both the industrial site and its access points, in the aim of preventing acts of malicious intent;

- ✔ Site location within a sparsely-populated sector in order to both limit the population's exposure to risks and enhance the proximity of local emergency services to speed on-site response times;

- ✔ Identification of the installation's specific hazard zones that are to be protected as a priority to avoid generating a secondary accident: identification of both explosion-risk and toxicity-risk zones;

- ✔ Knowledge of the risks associated with these specific hazard zones;

- ✔ Personnel evacuation in a situation of degraded operations under rapid conditions;

- ✔ Introduction of post-accident management procedures, on one hand to analyse pollutant concentrations (PAH, phthalates, PCB, dioxins/furans, metals) in the various surrounding natural media (water / air / soil and plants), and on the other hand to evaluate the potential impacts of these pollutants in their media, coupled with the appropriate remedial measures to be adopted.

Theme 2

Emergency preparedness and response

Emergency preparedness and response

At major hazard industrial sites, planning and responding to emergencies is a regulatory obligation. Its objective is to provide the site operator with the tools to manage an accidental, hazardous phenomenon with internal site resources (on-site preparedness and response) or to offer backup to public first responders, who have been notified by the operator in a timely manner, should the magnitude of this phenomenon lie beyond his control and/or jump the site boundary (interface with off site responders). The preparedness and response organisation studied in this document does not address workplace accidents but rather those involving manufacturing processes.

1. On-site response organisation

A well-designed on-site response organisation anticipates the proper and exhaustive identification of any hazardous phenomena that may arise on-site. This is one of the purposes of the safety report, since the selected accident scenarios make it possible to define both the right preventive barriers to implement along with barriers to lessen the impact of the accident and reduce any proliferation by acting pre-emptively. While fire remains the most common hazardous phenomenon for the majority of French industrial sites (see Fig. 1), the on-site response organisation must still not overlook other accidental phenomena specific to the site's activity i.e. those that differ from fire in their nature, frequency and speed - and which, nonetheless, require specialised response procedures and equipments - such as toxic leaks, anoxic atmospheres and environmental pollution.

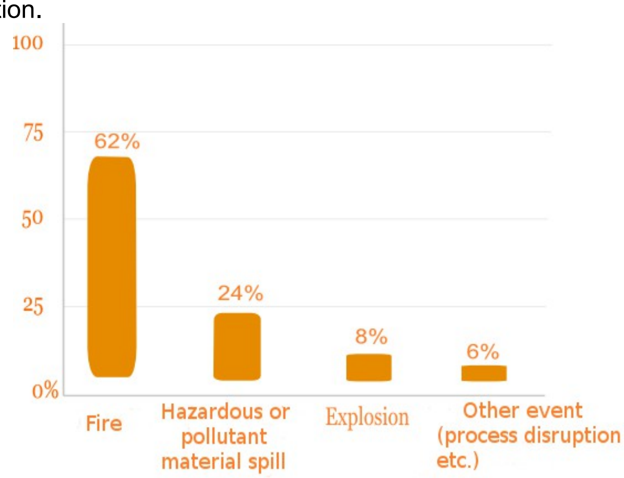


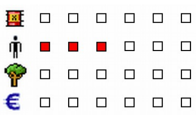
Figure 1: Typology of phenomena of over 26 727 French industrial accidents in the ARIA database, 1992-2012

The site's size and financial resources are determining factors for on-site response organisations: a small company often limits its efforts to training staff to the use of fire extinguishers, whereas an industrial platform combining several Seveso-rated facilities tends to be equipped with its own team of professional fire-fighters, in addition to teams of first responders and even second responders selected from among site personnel who have undergone the requisite training and drills.

An efficient on-site response organisation can be characterised according to the 4 following criteria:

1.1 Availability of operational and adapted technical response resources:

These resources can be broken down into several families: stationary or mobile, manually activated or automatic (Fig. 2). The advantage of a stationary means of extinction lies in its speed of deployment and proximity to the source of the hazardous phenomenon, thus making it recommended - or even mandatory - according to professional standards, regulations and facility insurers despite significant installation costs and maintenance constraints. Moreover, the widespread use of hazardous phenomena sensors now enables automatic activation, which saves time and minimises human presence outside of the site's normal business hours. Paradoxically, their operating speed and/or problems with settings/malfunctions can sometimes cause an accident or a secondary accident, as illustrated in the following summary:



ARIA 26999 - 27 April 2004 - 27 - GAILLON
In a coffin factory, fire broke out around 11 am in a 1500 m² varnishing workshop housing 500 kg of polyurethane and 20 litre cans of solvents. **Subsequent to activation of the automatic foam extinguisher and closure of the fire doors, the 20 employees present on-site inhaled foam; 5 of them were seriously**

affected and had to be hospitalised, while the other 15 were examined at the scene by first responders.

On the other hand, mobile fire extinction resources offer lower costs yet add the constraint of requiring set-up by on-site personnel trained to their use. In the event of an accident outside of normal business hours or in the presence of untrained staff, their proper deployment becomes uncertain and their efficiency may potentially be compromised.

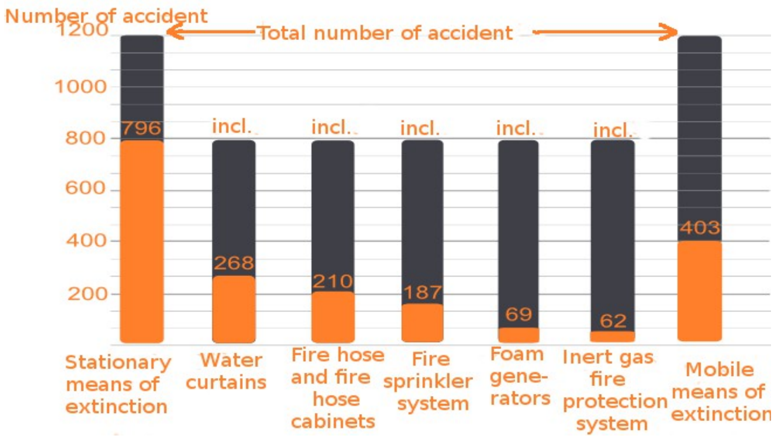


Figure 2: Distribution of extinction resources by type (sample of 1 200 accidents in the ARIA database)

It is important to remind that since extinction resources are in fact technical devices, they may fail due to internal causes (poor maintenance, improper settings, inadequate design) or external causes (domino effects, natural phenomena, utility outages), as shown in the following accident:

ARIA 41638 - 07 February 2012 - 13 - TARASCON
In a lower-tier Seveso-rated paper mill, fire broke out around 5:30 am in an outdoor storage zone containing 10,000 tonnes of wood bark. **Since the site's fire response network was inoperable, emergency crews installed 2 pumps on the RHONE 700 m away. Nonetheless, due to low temperatures, the water froze in the outflow pipes.** Fire-fighters were thus forced to let the entire inventory burn. During their intervention, many on-site machines also proved to be inoperable, experiencing mainly hydraulic defects like: frozen sensors, impossibility to open and close valves, and burst pipes. Major physiological constraints also interfered with the response effort: frostbite led a number of first responders to seek medical attention.

1.2 Allocation of well-trained human resources:

On an industrial site, the ability to efficiently control a hazardous phenomenon often presumes the action of on-site employees, given their proximity to the unfolding accident. The severity and magnitude of the accident depend on the speed and efficiency of the response by staff. Their training and the refresher courses offered are thus critical components when organising emergency services. This instruction must cover two aspects:

- knowledge and a strong understanding of the hazardous phenomena occuring within the installations, so as to provide the response personnel with a realistic perception of the hazards thus avoiding a behavioural response of panic or risk-taking;

- response techniques. Training modules will be more extensive and frequent as the resources that enable personnel to control hazards become more specialised: spraying a fire extinguisher is quite different from operating a foam nozzle while wearing a Self-Breathing Apparatus.

1.3 Establishment of response procedures:

Like any organisational effort, setting up on-site response organisations assumes prior consideration has been given to coordinating available technical and human resources through defining roles and staging "typical" response scenarios adapted to the primary hazards identified. This approach is formalised as a mandatory emergency plan or, for Seveso-rated sites and specific designated high-risk facilities, a mandatory internal emergency plan to be revised every 3 years. The procedures associated with this plan must be consistent with the accident scenarios selected in the safety report or hazard assessment. However, when the current situation no longer corresponds to these scenarios, the procedures must be flexible enough to assist the response team leader in making the right decision without forcing the implementation of techniques that would not be appropriate. The following accident indicates that the lack of formalised procedures as part of the emergency plan may be an exacerbating factor:

ARIA 45008 - 03 March 2014 - 71 - BRANGES

At around 5:15 am in a poultry slaughterhouse, an ammonia leak was observed on a solenoid valve placed on refrigeration installations. 183 employees had to be evacuated, 30 of whom received treatment by first responders and 6 were transferred to hospital. The following exacerbating factors were identified: **1. an inefficient evacuation (no alarm sounded, no guidelines issued by plant managers); and 2. an unsuitable operating protocol for responding in the event of a NH_3 liquid phase leak** (difficult access to shut-off valves trapped in the ice, inappropriate protective equipment). **The plant operator requested revising both the response and evacuation procedures,** validating them through drills and acquiring NH_3 measurement devices.

1.4 Scheduling and practising regular drills:

The incidents and accidents requiring the mobilisation of on-site response organisations (fortunately) prove to be quite infrequent at any given industrial site. For this reason, regular response team drills are necessary to ensure the on-site response organisation remains fully efficiency in the long run. The diversity of scenarios, and sometimes the diversity in resources deployed, justifies the regular scheduling of drills. Such exercises also offer the opportunity to determine what needs to be improved or revised, in regards of both equipment and procedures. It remains necessary however to clearly identify the realistic limitations assigned to these drills, so as to avoid needlessly subjecting personnel to risk or causing an accident.

ARIA 11160 - 19 October 1996 - MIESBACH - Germany

Inside the warehouse of a waste recycling company, during a fire drill, **a professional fire-fighter lit a smoke bomb to simulate a fire. The firework ignited, and the ensuing fire spread to stored materials, setting the entire building ablaze.**

2. The interface with off-site response organisations

The on-site response organisation must also plan "operational" early warning systems to alert off-site response organisations that might be called to assist in emergency operations: public first responders, the mayor of the municipality, a designated service provider (specialised response equipment), and field support units (experts and instruments). This "operational" early warning system shall also alert services that may be called to help reduce accident severity, whether on-site (utility suppliers) or beyond (neighbouring plants, public facility managers), and to those governmental agencies that shall be mandatory informed by law (eg. environmental control agencies).

Should the resources available offer the possibility, these various systems must also include informing the entities that might be involved: local authorities, the press, neighbours, agencies monitoring environmental quality (air, water), and the company's on call manager. Even if the internal situation has been brought under control, a flawed external information release could actually cause panic or confusion among local residents, or incite them to needless exposure out of curiosity; moreover, poorly informed local authorities or administrative agencies might not be able to reassure the public or prepare deployment of the resources that sometimes prove necessary (through the off-site emergency plan).

ARIA 40495 - 22 June 2011 - 69 - FEYZIN

Shortly before 9 am, strong gas smells were noticed across the Lyon Metropolitan Area, generating widespread concern and population movements. Over 1000 calls, randomly triggering 5 response procedures for a gas leak, were received by emergency services within an hour. Three victims suffering slight breathing problems had to be treated. Large volumes of calls were also recorded by the police department, town halls and the gas utility office. Many office buildings, retail establishments and residences were spontaneously evacuated. The oil refinery management sought the means to avoid a repeat of this episode and ways to improve the plant's capacity to react to odour outbreaks, which are not necessarily incidental in nature. **The authorities deplored that the information was delivered by the refinery with a delay (2 hours after the event), which did not help assuage residents' unease.**

Let's also recall that while a Seveso plant's internal emergency plan does initiate coordination with the public first responders, such is not the case for all emergency plans adopted at industrial sites. Moreover, the criteria for activating an emergency plan vary from one kind of operator to the next. Figure 3 reveals that for incidents and accidents arising at France's Seveso plants between 2007 and 2013, the internal emergency plan was triggered no more than 1/3 of the time. Some operators are ready to initiate the plan pre-emptively even in the case of a minor incident, while others (especially those organised with a well-equipped on-site team of responders) sometimes decide not to inform public first responders in assuming that their in-house resources are sufficient to handle the situation and that the arrival of fire-fighters might complicate ongoing operations.

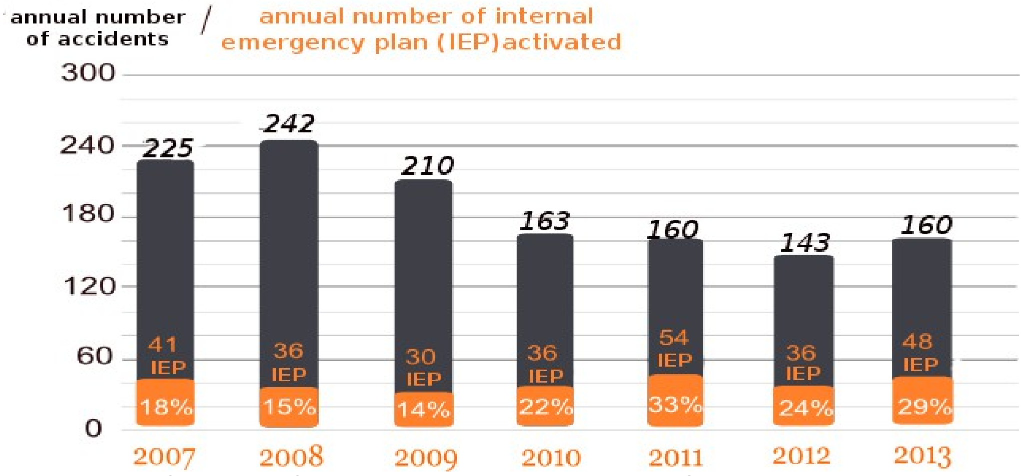


Figure 3: Rate of activation of internal emergency plans at France's Seveso plants, 2007-2013

The risk is that public fire-fighters, inadequately informed by external witnesses, arrive on the scene with inappropriate fire-fighting equipment and lose precious time in setting up and becoming familiar with the ongoing situation. In terms of best practices, it is thus critical for the plant operator to notify public emergency services as soon as he suspects an abnormal situation is turning serious, even if it is felt that internal resources can handle the challenge. Such is the premise of 12 January 2011 circular issued by the French Ministry of the Interior, which notes: "*It is preferable for the operator or his representative to inform public first responders of the occurrence and evolution of an event that has led to activating the internal emergency plan.*"

Beside accidents, this kind of coordination would be worth developing when conducting joint on-site drills. The strategy would improve public fire-fighters' knowledge of the site, its organisation, hazards and specific aspects of response equipment assigned for deployment. Above all, it would allow both parties to speak the same language as regards hazardous process and materials. The difficulties of such joint drills, however, should be underlined: availability of both parties, greater preparation time, last-minute uncertainties that may lead to the drill’s cancellation, and lastly the financial participation operators must pay to public first responders in France (potentially exceeding €100,000 for a deployment of major response equipments on a large industrial platform).

Conclusion

The on-site response organisation remains an essential component of industrial facilities safety and reflects the balance struck by the operator between means of prevention and protection. Like any organisation, it presumes an effective identification of needs (risk analysis and the ensuing hazardous phenomena), rigorous preparation and a guarantee of the timely availability of both technical and human resources. While the magnitude, means employed and type of hazardous phenomena vary from one industrial plant to another, the guideline still calls for the existence of a continually-updated emergency plan, along with its associated tools (emergency instructions sheets, alert directory, facilities’ plans, inventory status report) and the scheduling of drills on a regular basis.

The site's environment must also be taken into account in this organisation since an event - that may be well under control on site, yet still perceptible off site - might create confusion and needlessly trigger the deployment of large-scale public first responders. The communication aspect involving actors external to the site cannot therefore be overlooked, even though regulatory obligations remain limited in this regard.

Accident during an "Emergency Plan" drill

11 June 2013

Tilloy-Lez-Cambrai (Nord)

France

Automatic extinction
Emergency plan
First response
Evacuation
Human factor

THE FACILITIES INVOLVED

The site:

The plant has a workforce of some 200 people (see Fig.1). Given its activities, it is subject to environmental permit. The products manufactured at the Tilloy-lès-Cambrai site are as follows:

- Hollow glass microspheres for industry and the oil sector
- Glass beads (solid backlit glass microbeads)
- Retro-reflective adhesive tape adapted to ground markings for the traffic signal market
- Industrial adhesives (glues, sealants, coatings).

Figure 1 : Aerial view of the plant (source : Fabrice Loze, ARR)

The involved unit:

This accident occurred in a building housing the Adhesives unit (Fig. 2); the building contained a total of 7 rooms. Mixing workshop room no. 6 was laid out with 2 exit doors: a primary door accessing the main building hallway and featuring a fire proof door with a controlled closing mechanism; and an emergency door leading outside the building and fitted with an anti-panic closing system.

Each room was equipped with a fire extinction system relying on CO_2 injection that operated as follows:

- presence of 2 fire detection cells: thermal and optical (flame detector);
- one of these means of detection triggered the personnel evacuation siren;
- the two detection sources (if simultaneous confirmation of both alarms) controlled automatic CO_2 injection activation in the targeted room, after an 18 to 20 seconds self-timer delay, allowing the time necessary for employees present to evacuate;
- at the end of the self-timer delay, the fire door of the particular room closed automatically.

CO_2 was injected into the rooms by saturation thanks to a reserve composed of 76 kg bottles located outside the building. In room No. 6, the system comprised 8 injection nozzles positioned at the top and capable of being activated in either automatic or manual mode (with a manual CO_2 trigger placed near the emergency doors).

To complete this fire protection system, the building was also protected by a sprinkler type installation (Fig. 2).

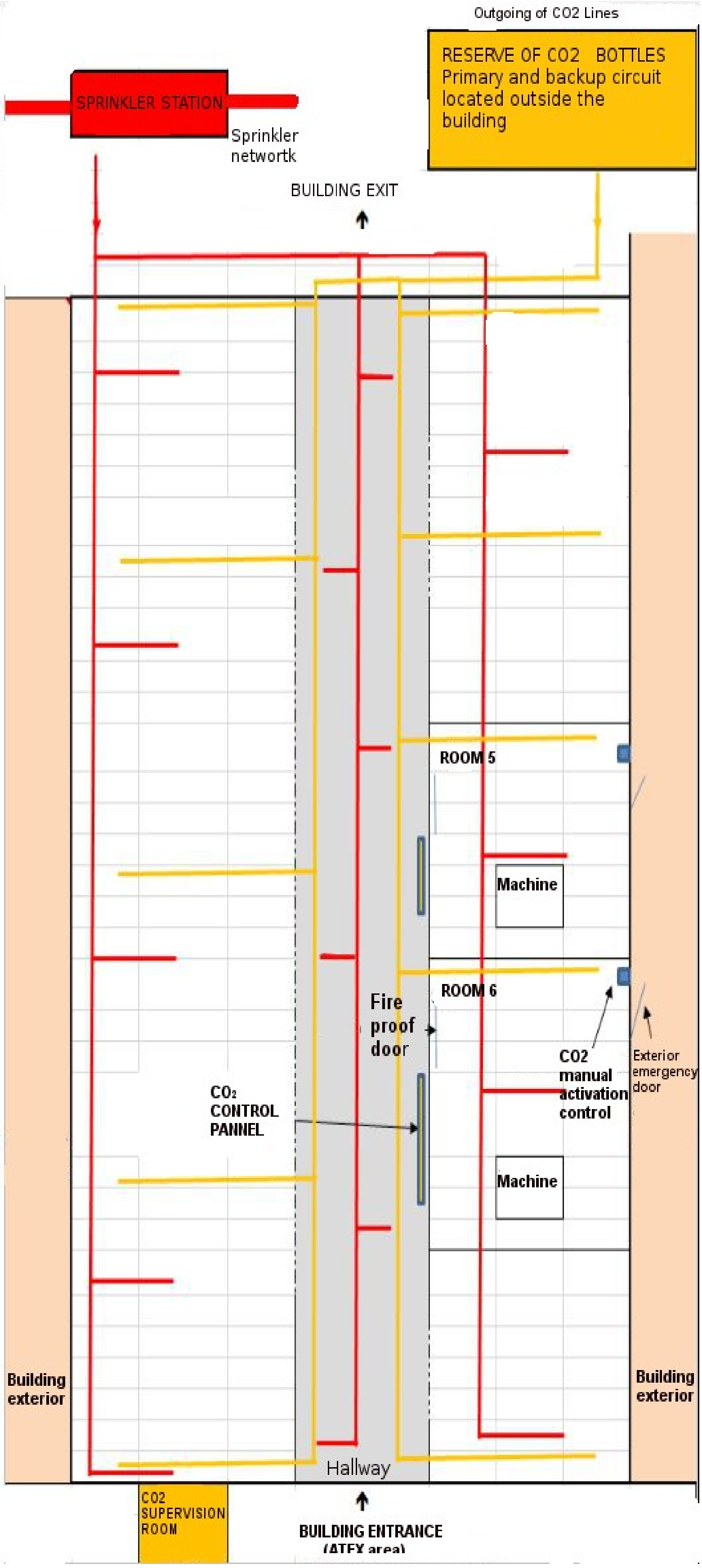


Figure 2: Fire protection devices inside the adhesive workshop building (source: DREAL NPDC)

THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

The accident:

The drill was intended to test the site's emergency plan. Several observers not affiliated with the site were present on this particular day: the local government representative, representatives of an expert fire prevention body (CNPP), police officers, and fire-fighters. The drill was scheduled to start at 9:30 am and act the following scenario:

- Simulated exothermic reaction with smoke candles placed in Room 6;
- Closure of the primary door to Room 6;
- Activation of the CO_2 injection and saturation of Room 6 with CO_2;
- Reconnaissance by 2 responders (a maintenance technician and a subcontracted security agent);
- Ventilation of Room 6 to extract the CO_2;
- Positioning of a dummy victim (another security agent who had participated in preparing this drill);
- Evacuation of the dummy victim by the 2 responders working as a pair.

The Head of "Safety & Security", responsible for the site's fire protection, supervised the emergency response operations in accordance with his "response" function as stipulated in the emergency plan. Both responders were experienced (over 10 years of seniority each at the site) and trained in the site's Emergency Plan (EP) procedure. They were wearing emergency gear, namely a self-breathing apparatus.

An employee with the specialised subcontractor in charge of maintaining the CO_2 protection installation was present for the drill and assigned the mission of:

- Disconnecting the CO_2 extinction of the building's other rooms before initiating the drill;
- Choosing, from among the bottles supplying CO_2 to these rooms, those bottles to be installed for subsequent retesting instead of the recent bottles supplying Room 6 (in the aim of optimising consumables).

His firm was informed ahead of time that the drill was scheduled to begin at 9:30 am.

In reality, the drill did not take place as planned and instead proceeded by the following accidental sequence:

At the outset of the drill, everything progressed according to plan. The Head of "Safety & Security" installed smoke candles in Room 6 to simulate an accidental exothermic reaction occurring during the process. After evacuating the personnel present in the room, the fire door was closed.

The subcontractor's employee had not finished interchanging the CO_2 bottles supplying each of the adhesive building's rooms. The "Safety & Security" manager had not been informed of this delay and continued the drill by activating the manual "general evacuation" alarm at the building entrance. Upon hearing the siren, the site's workforce collected at the various designated gathering points.

The two responders (designated emergency plan intervention duo) equipped with their self-breathing apparatuses stood opposite the fire door to Room 6 in the building hallway. The "Safety & Security" manager informed them by radio of the place where the alarm would be sounded to trigger the general evacuation. The 2 agents then waited for instructions from this manager, who was now assuming the role of response coordinator. To simulate a search for victims, he asked these agents to wear their self-breathing mask and prepare to enter Room 6 once the CO_2 injection was over.

An **initial deviation** occurred. It was actually necessary to wait 20 minutes before the subcontracted employee confirmed to the manager that the task of preparing bottles for the "CO_2 blast" had been completed. This unexpected delay seriously upset the manager, who in the meantime had to go back and forth inside the building to monitor the blast preparation. Moreover, the external observers - including a high-ranking official - were anxiously awaiting the rest of the drill. From his vantage point, the security agent playing the dummy victim's role interpreted this delay as a cancellation of the CO_2 blast. It was at this point that the **second deviation** arose: unknown to the other drill participants, this agent entered Room 6 without having received any instruction to do so.

A few minutes later, the manager returned towards the exterior emergency door to Room 6, where two observers were waiting for him. In his haste, he manually triggered the CO_2 injection: the warning siren rang for 20 seconds in the room, then the injection procedure was initiated. This decision constituted a **third deviation** since the planned scenario called for the security agent - in the subsequent role of dummy victim - to activate the injection and not the manager.

A **fourth deviation** simultaneously appeared when, inside Room 6, the dummy victim did not react to the siren announcing activation of the CO_2 injection. In compliance with instructions given to employees, the victim should have immediately left the room. Instead, he remained standing underneath the injection nozzles as the CO_2 spread. The victim quickly fell to the ground unconscious due to the anoxic atmosphere filling the room.

In seeing this turn of events through the window of the emergency door, the manager decided to rescue the victim by holding his breath. He took backward steps in dragging the inanimate body of the dummy victim towards the emergency door. Since visibility in the room was reduced subsequent to the injection and smoke candles, he fell into the pit on the platform lift used to load products into the mixer. During his fall, he instinctively inhaled and also lost consciousness. The two "real" victims of this drill were thus both close to the exterior emergency door to Room 6, yet were lying motionless on the floor. The two responders wearing self-breathing apparatuses, who were waiting in front of the room's primary door to evacuate the dummy victim, did not react due to a lack of visibility or instructions received by radio.

The two observers adjacent to the emergency door thus decided to rescue the victims and entered the room holding their breath, while the third observer notified the crisis unit. The drill was immediately halted and the emergency plan activated for the real accident that was unfolding. Employees present near the building hurriedly provided an initial oxygen relief to the two victims using self-breathing masks and then an oxygen bottle. The departmental rescue services, also present as an observer, assumed responsibility for the 2 victims and their rescuers, who had also been exposed to CO_2.

Consequences of this accident:

The consequences of this accident were solely human: 5 people (4 employees and 1 security agent working with a subcontracted firm) had to be treated subsequent to CO_2 exposure:

- 3 of them were admitted to the town of Cambrai Hospital and released at the beginning of the afternoon (2:30 pm).
- 2 others sustained more serious exposure and had to be transported by helicopter for treatment in a decompression chamber at the town of Lille Hospital. They were released at the beginning of the evening (8:20 pm).

This drill also revealed a series of technical defects on the CO_2 injection installation, yet these had no bearing on the accident:

- A leak on the CO_2 supply line at the level of a union connection. This leak was observed in the building hallway in the vicinity of Room 6.
- A malfunction on a CO_2 line check valve caused the tapping of 13 CO_2 bottles instead of the 9 intended for Room 6

European scale of industrial accidents:

By applying the rating rules applicable to the 18 parameters of the scale officially adopted in February 1994 by the Member States' Competent Authority Committee for implementing the 'SEVESO' Directive on handling hazardous substances and in light of available information, this accident can be characterised by the four following indices:

The parameters composing these indices and their rating methodology are available on the Web page: http://www.aria.developpement-durable.gouv.fr.

The "hazardous substances released" index was scored a "0" since no substance included on the Seveso Directive Appendix I list was actually released.

The "human and social consequences" index received a "2" rating due to the 5 individuals exposed to CO_2 and hospitalised for a period of less than 24 hours.

The "environmental consequences" index was not rated given the absence of any environmental impacts.

Lastly, the "economic consequences" index was assigned a "0" score as the result of no direct damage to any of the site's production or safety equipment.

THE ORIGIN, CAUSES AND CIRCUMSTANCES OF THE ACCIDENT

Many investigations were conducted by the plant Committee for Hygiene, Safety and Working Conditions (CHSCT), and a causal tree analysis was carried out. Conclusions on the causes of this accident were as follows:

- The drill got under considerable anxiety due to:
  - the presence of a number of external officials, who were there specially for the occasion;
  - the delay in setting up the CO_2 bottles (for the blast) by the company specialised in CO_2 maintenance;
  - the extra time required to start the drill and assemble the crisis unit.

- Failure to follow the planned and validated scenario:
  - The staging of this drill was delayed due to the time required to set up the CO_2 bottles. This delay created some unplanned dead time between the general evacuation and triggering of the CO_2 injection;
  - During this idle period, the dummy victim entered Room 6 by the emergency door without first receiving the instruction to do so. The external observers did not see him enter. For his part, the "Safety & Security" manager was busy inside the CO_2 utility room located 30 m from Room 6;
  - Upon his return to the CO_2 room, this manager proceeded to manually activate the CO_2 injection, in the place of the security agent (in the role of dummy victim), in violation of the initial plan.

- The drill scenario was not precise enough. Moreover, it did not sufficiently detail the tasks to be carried out, at what specific times and by whom.

- Problems in perceiving the situation and/or establishing communication between drill participants:
  - The "dummy victim" thought that the CO_2 bottle blast had been cancelled. No instruction regarding the blast had actually been given to him for 20 minutes following the beginning of the drill, especially given that this victim was, according to the scenario, responsible for unleashing the blast;
  - Not imagining that the blast could still be on the program, the "dummy victim" paid no attention to the sound of the CO_2 siren or the injection pipe pressurisation alarm. This employee remained standing under the injection nozzle, despite being trained in CO_2 risks and possessing 10 years of experience as a security agent;
  - The "Safety & Security" manager was responsible for both organising the drill and overseeing its operations. If an unexpected event arose, he was incapable of seeing the big picture so as to analyse all consequences for the ongoing drill and adapt his response. Best practices in the area of on-site drills stipulate that organisers are to solely act as observers during the drill exercise.

ACTIONS TAKEN

Subsequent to this accident, a short-term action plan was immediately drawn up; it focused on verifying both the workshop atmosphere and CO_2 injection installations, for the purpose of resuming production (ventilation of the room and hallway, verification of safety servo-controls, etc.).

Next, the following actions were conducted:

- Production of a causal tree as of the following day, along with an associated action plan;
- Information feedback to authorities attending the drill (Environmental Agency, Labour Inspection, pension fund/workers' compensation insurer);
- Internal investigations in conjunction with the Health and Safety Technical Committee;
- Technical analysis with the firm specialised in maintaining the CO_2 injection installation, in order to confirm the 2 technical anomalies detected, and then rectifying them;
- Completion of a second verification and test of the entire installation during its various modes of operations (automatic, manual and idle);
- Introduction of a lockout mode (padlocked grating) on the console ordering the manual activation or shutdown of the CO_2 extinction system, as well as on both the primary and backup line boxes;
- Recall of CO_2-related risks during special CO_2 training sessions offered to personnel and when training new recruits;
- Modification to the security rounds (to include verifications of the manual CO_2 extinction control tables);
- Update of the procedure for manual activation or shutdown of the CO_2 extinction system;
- Review of the CO_2 protection services contract with the maintenance firm specialised in CO_2 injection: increased frequency of pipe inspections, replacement of check valves;
- Audit by the expert body of the CO_2 protection installation in the presence of the maintenance specialist;

- Emergency Plan update incorporating feedback experience from the accident: integration of each scenario identified into the plan, addition of the procedure overseeing the drill exercise.

LESSONS LEARNT

The main lessons drawn from this accident are the following:

- Every aspect of the planned and validated scenario for a safety drill must be respected. The scenario cannot be changed at the last minute. Only a formalised change and its validation by the Head of Emergency Response or Director of Internal Operations (for SEVESO-rated sites) can be authorised.
- The scenario must clearly indicate "who is controlling what for each step?" in order to guarantee that all risks are being effectively managed. This drill never should have started as long as all planned conditions had not been met.
- The Emergency Plan must contain the main scenarios anticipated (major risks) based on the safety report dedicated to site installations.

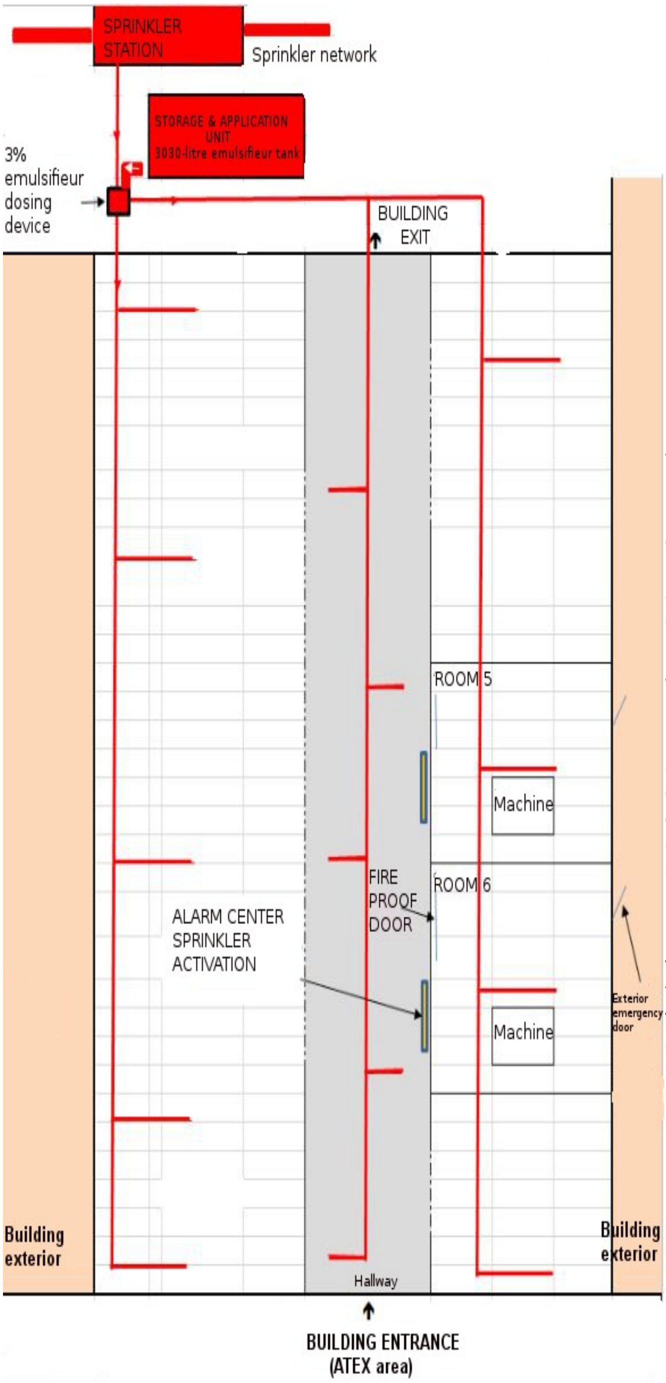


Figure 3 : New configuration of the fire protection systems deployed in the adhesive workshop building (source: DREAL NPDC)

This accident led the facility operator to reflect on the relevance of his CO_2 protection installation. An audit, requested of the CNPP fire safety body, convinced the operator to change his fire protection strategy. CO_2 injection was replaced by a modification to the existing sprinkler system, with the addition of a 3030 litre emulsifier tank.

This decision was accepted by the site's insurer. The principal advantage of this new installation lies in improved personnel protection; it actually eliminates all risks of creating an anoxic atmosphere. Its disadvantage pertains to the risk of equipment deterioration following the presence of water and emulsifier should a fire ignite, thereby requiring deep cleaning for all such equipment.

Modification to the existing sprinkler system, coupled with the addition of emulsifier, was performed during the 1st quarter 2015. Each room in the adhesive workshop is now equipped with the following detection system (Fig. 3):

- 2 fire detection cells: one thermal the other optical;
- One or the other of these 2 detection devices controls the overall site's personnel evacuation siren, with an alarm relay to the safety unit;
- Both detections (provided confirmation of the two alarms) are able to trigger: the safety servo-controls (energy outage), the room's pneumatic and electrical siren, and the alarm relay to the safety unit.

This new design of fire protection system operations (replacement of the CO_2 installation by a "sprinkler + emulsifier" device) is also being shared at the Group level and has triggered modification projects at other sites.

Untimely injection of foam into a warehouse containing phytosanitary products

30 April 2012

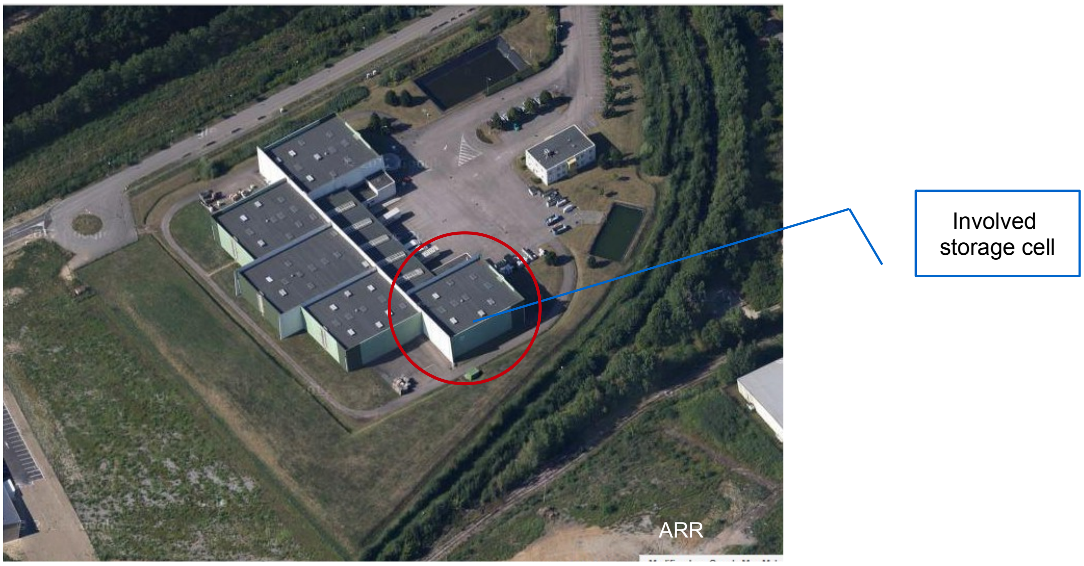
Ludres (Meurthe-et-Moselle)

France

Communication
Warehousing
Automatic extinction
Internal Emergency Plan
Emergency response

THE FACILITIES INVOLVED

The site:



This subsidiary of a major farm cooperative group is specialised in the provision of agricultural services, primarily in the areas of plant health and hybrid seeds (R&D, logistics, technical and administrative support services).

The Ludres site is a logistics platform for phytosanitary products and seeds with a "Seveso upper tier" rating. Its authorised storage capacities consist of:

- 3000 tonnes of environmentally hazardous products, known to be toxic or highly toxic for aquatic organisms;
- 200 tonnes of products known to be toxic for humans;
- 14 tonnes of products known to be highly toxic for humans;
- 4000 m^3 of flammable liquids divided into various categories, for an equivalent of 2000 m^3.

The site only stores products that fit into small containers, to be directly used by the end consumer; it handles the operations (like picking) involved in palletising the various products ordered by clients. The containers are not opened on-site, except in the event of an accidental burst.

The warehouse is composed of 7 storage cells ranging from 60 to 1250 m² with a 10 m height (3 m for the 60 sq. m² cells), each one of which is assigned to specific hazardous substances (see Fig. 1). The cell walls have a fire resistance rating of 120 minutes. Cell doors have been fitted with automatic closing devices, while the cells themselves are protected against fire by means of an automatic extinction system that relies on foam flooding.

The automatic foam extinction system features a 5000 litre emulsifier reserve plus a 120 m^3 autonomous reserve of anti-freeze fluid. The system was designed to fill a cell in less than 5 minutes and flood 2 cells simultaneously. The warehouse was also equipped with ancillary facilities: boiler room, shipping dock, workshop for charging vehicle accumulators, shipping administration offices, and a few refrigerators for storing refrigerated products.

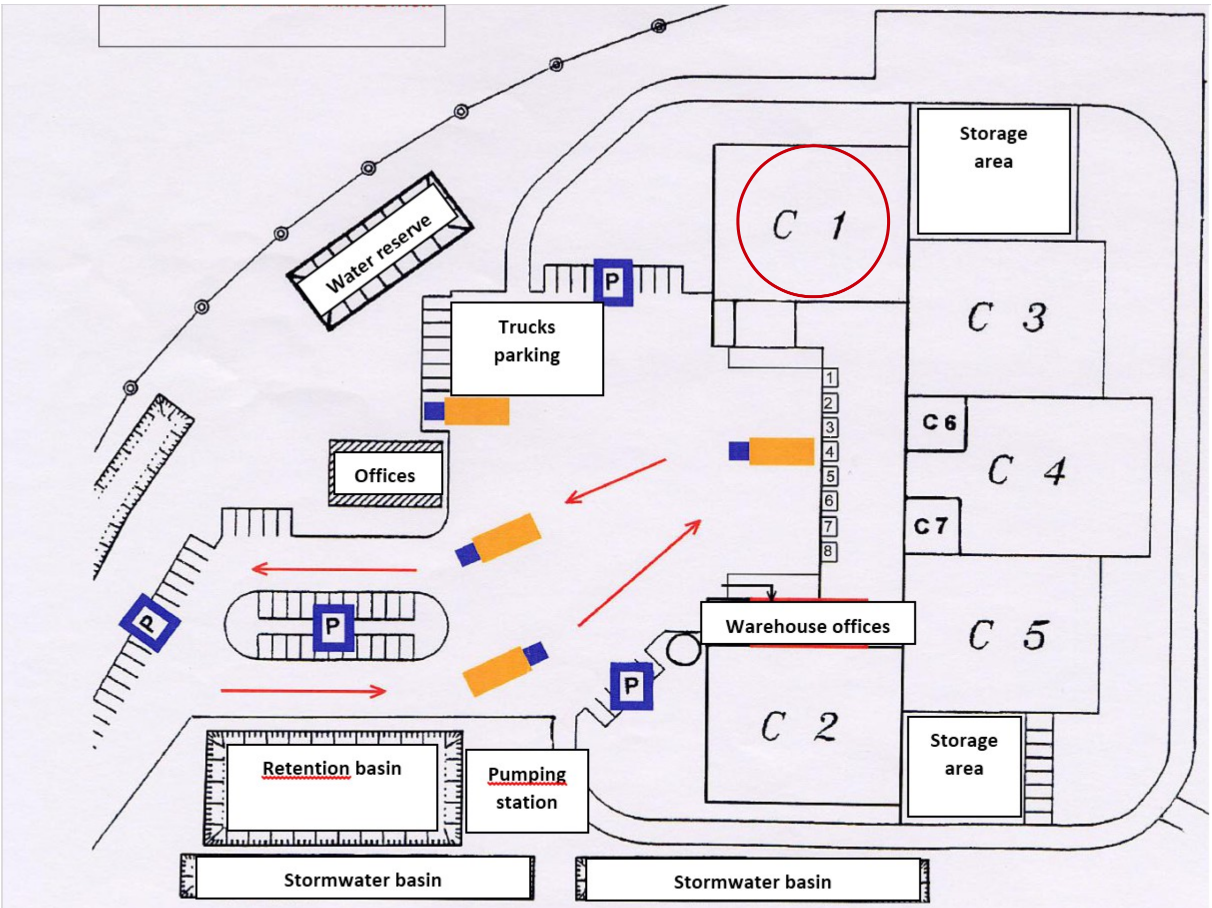


Figure 1 : Layout of the logistics platform (ARR)

The involved unit:

Cell 1, laid out over a 1000 sq. m² floor area and 10 m high, stored flammable and/or toxic or highly toxic substances for humans (Fig. 2). Like the other cells, it had been fitted with metal storage racks.

Figure 2 : Interior of Cell 1 (Source Operator - ARR)

THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

The accident:

The chronology of events during this accident was as follows:

Monday 30 April 2012:

- 6:56 pm: Fire alarm triggering foam injection relayed to the offsite surveillance firm.
- 6:57 pm: The surveillance firm called the warehouse manager, who did not answer: the firm left a voice message.
- 6:58 pm: The surveillance firm called the head of the "warehouse unloading" crew, who did not answer either, and left a voice message as well.
- 7:00 pm: The surveillance firm then called the head of the "warehouse loading" crew, who answered the phone: this employee was duly informed of the situation.
- 7:02 pm: Next, the surveillance firm called the Sales Manager, who also answered and was provided the same update of the situation.
- The internal emergency plan response sheet stipulated that the surveillance firm, after having phoned these 4 managers, was to alert fire-fighters by dialling "18" (the French national fire emergency number). On its log entry however, the firm indicated at 7:06 pm: "Contact number for fire-fighters unknown".
- Around 7:15 pm: Arrival on-site of the loading crew manager, who observed that Cell 1 was filled with foam; he closed the gas intake at the shutoff valve, located outside the boiler room and designed for this purpose.
- 7:22 pm: The warehouse manager called the surveillance firm back to request confirmation of the situation.
- 7:27 pm: The loading crew manager called both the fire department and emergency services, though he dialled the local fire station number directly instead of the "18" national fire emergency number.
- 7:31 pm: The site's "diesel fire pump fault" alarm was tripped, with relay to the surveillance firm, which immediately called the warehouse manager to inform him that the diesel pump unit was no longer available.
- Around 7:35 pm: Arrival of the warehouse manager, who turned off the site's general electricity supply.
- 7:36 pm: On its log entry, the surveillance firm indicated having received instructions from the warehouse manager to notify the fire services switchboard. Unaware of this phone number, the firm contacted the police station closest to the site, who connected them to this switchboard. The local fire department operator informed the firm that a response team was already on its way to the site.
- Around 7:40 pm: Arrival of the local fire-fighting team at the scene, followed shortly thereafter by the "unloading" crew manager, who provided fire-fighters with a current inventory status of the various storage cells from the dedicated storage pocket found in the fire protection room.
- Around 8:00 pm: Despite the absence of any visible signs of fire, fire-fighters decided to inspect Cell 1: three fire-fighters roped together wearing insulated self-breathing apparatuses penetrated into the foam that covered the adjacent premises in order to access the door to Cell 1 (Fig. 5). A few minutes later, two of them exited the cell in a state of physical exhaustion while the 3rd member was reported missing. Another reconnaissance effort found him unconscious lying on the floor in a state of cardiorespiratory arrest. He was quickly resuscitated and then transported to hospital in a critical condition.
- Around 8:20 pm: Arrival of the Sales Manager at the facility.
- Around 8:45 pm: Fire-fighters decided to open the loading dock doors, under the supervision of the "unloading" crew manager.
- Around 9:30 pm: The warehouse manager completed a round to ensure none of the surface water had been polluted (retention basin, channel).

Thursday 3 May 2012: The fire-fighter found unconscious died in hospital. The autopsy did not state the cause of death, even though the hypothesis of asphyxiation from the foam was the only plausible explanation.

The consequences of this accident:

No fire had occurred, hence no toxic fumes were released and the emergency services did not deploy any specific means of extinction. The foam was confined to the site, outside of a few packets carried by the wind.

In terms of human consequences, one fire-fighter died. No other human consequences were reported; moreover, no neighbours had to be evacuated and no water, electricity or phone services had to be cut.

The wild flora and fauna were not affected by this accident. Neither groundwater nor surface water nor any soils were polluted.

The economic consequences for the farm cooperative warehouse were significant (i.e. €750,000), as a result of:

- round-the-clock (24/7) site monitoring (excluding warehouse opening hours) due to the lack of an operational automatic fire detection system for over a year;
- damage sustained by the fire extinction system (pump destroyed, emulsifier stock depleted, etc.);
- operating losses tied to reduced activity schedules imposed by administrative and judicial authorities for 6 weeks;
- the requirement to repackage a number of bottles, including the destruction of some that had become unsellable (Fig. 3).

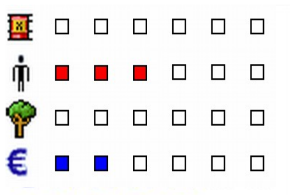
According to the site operator, these economic losses were compensated in full by the insurance policies.

Figure 3 : Cell 1 after activating the foam extinction
(Source Operator - ARR)

European scale of industrial accidents:

By applying the rating rules applicable to the 18 parameters of the scale officially adopted in February 1994 by the Member States' Competent Authority Committee for implementing the 'SEVESO' Directive on handling hazardous substances and in light of available information, this accident can be characterised by the four following indices:

Hazardous substance released
Human and social consequences
Environmental consequences
Economic consequences



The parameters composing these indices and their rating methodology are available on the Web page: http://www.aria.developpement-durable.gouv.fr.

The "hazardous substances released" index was scored a "0" since no substance on the list referenced in Appendix I of the Seveso Directive was actually released.

The "human and social consequences" index was assigned a "3" rating due to the death of a fire-fighter directly related to his entry into the storage cell implicated in this accident.

The "environmental consequences" index could not be evaluated since no environmental impacts were recorded.

The "economic consequences" index received a "2" rating due to the cost of monitoring operations and the extent of operating losses stemming from both a decline in business activity and stock damaged by the foam.

THE ORIGIN, CAUSES AND CIRCUMSTANCES OF THE ACCIDENT

This accident was caused by a technical malfunction of the automatic extinction system, which under normal conditions should not have resulted in human consequences. The incident however was exacerbated by circumstances surrounding the emergency response, as well as by the type of extinction foam.

Key event: The accidental injection of foam into Cell 1

The untimely signal that had caused an automatic foam injection in the cell was due to wear on the cable connecting a manual trigger with the site's programmable safety controller. During the month following the accident, several fire detection incidents were recorded by the fire station, all of which were aberrant and stemmed from one of the two Cell 1 manual triggers, while not being able to identify precisely which one. A detailed inspection of the cables revealed wear and tear marks and on one of them, which generate a recurrent fault.

The fire safety system had been designed to limit these unscheduled injections by servo-controlling the motorised pump start-up to fire detection by means of two different detectors. In the case of the manual triggers however, just a single signal was necessary: no redundancy had been built in.

Exacerbating event: Confusion between an ICPE category number and the UN number used when transporting hazardous substances

Fire-fighters with the first response team arriving on-site asked the operator to provide them with the latest inventory status report. The operator obliged by producing a printed document, generated upon completion of the most recent work day and easily accessed from the room containing fire protection equipment. This step had been regularly performed during annual meetings held on-site between warehouse management and local emergency services. The last such meeting had actually taken place just 3 days prior to the accident. The deceased fire-fighter had been present at that meeting and, given his knowledge of the premises, volunteered to be part of the group entering the warehouse.

When fire-fighters became aware of this "printout" version of the cell's inventory, they assumed that the numbers used by the warehouse operator to classify the various stored products and their weights corresponded to the current UN numbering system for transporting hazardous substances, whereas in reality they corresponded to the French ICPE (designation for environmentally sensitive installations) category numbers associated with these products.

Among the numbers listed in the report, i.e. category no. 1510, the storage of combustible materials under the ICPE regulations was mistaken for the same UN number, which corresponded to Tetranitromethane, a toxic combustive product (see Fig. 4). Responders thus considered that, despite the absence of visible signs of ignition from the outside, a fire might have been smouldering within the foam and moreover fed by this combustive product. Accordingly, a physical investigation by a three-member team wearing self-breathing type masks was decided so as to remove this doubt.

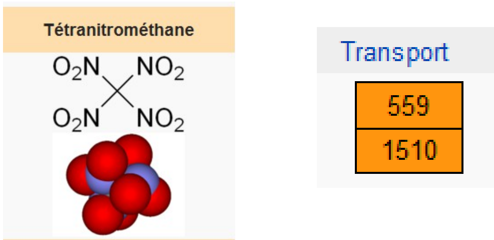


Figure 4 : Tetranitromethane and its 4-digit UN code, identical to that under the heading entitled "*Storage of combustible materials, products or substances in enclosed warehouses*" listed in the French ICPE installation nomenclature

Exacerbating event: The danger from foam being injected into the building

The two surviving fire-fighters of the three-man reconnaissance team, as well as the members of subsequent investigation parties, reported that the foam inside the buildings did not display the same consistency as that observed outside. They all complained of real difficulty in advancing into the foam, which entailed coping with a highly viscous substance that constrained any kind of movement. They also expressed that the foam had been an obstacle to vision, to such an extent that a hand placed in front of the eyes remained invisible. Similarly, the foam acted as sound insulation, thus preventing verbal exchanges (besides radio) with the other two fire-fighters in the trio. In addition, they mentioned that shortly before exiting the premises, the foam wound up penetrating inside their breathing masks. The team's progress had been slowed to a point that they were not even able to enter Cell 1 and had to turn around barely after reaching the door (red dot in Fig. 5).

The foam that had reached the building exterior, either after opening some doors or via seams in the walls, did however immediately exhibit a consistency similar to that initially applied outside.

Fire-fighters were trained in the use of insulated breathing apparatuses, including under stressful situations, and were very familiar with the time needed to empty the bottles. Nonetheless, on the day of the accident, the assigned responders consumed air roughly twice as fast as normal and experienced an abnormal level of fatigue, nearing exhaustion.

Following the enquiry, emergency services concluded that the foam viscosity had caused both excess oxygen consumption and the formation of a film on the relief valve appended to the mask. This film in turn raised the valve's opening pressure, thus building up pressure inside the breathing mask and causing the appearance of empty spaces between the responders' faces and masks.

The hypothesis forwarded to explain these observations was that the foam, theoretically of high bulk (i.e. a foam of limited density), had transformed into a low bulk foam as a result of confinement created by the premises and pressure generated by the height of stacked foam. A rough calculation shows that 120 m^3 of water and 5 m^3 of emulsifier injected into a 10,000-m^3 cell yields an average bulk of 80 (in comparison, a bulk above 200 is considered "high" and one below 20 "low").

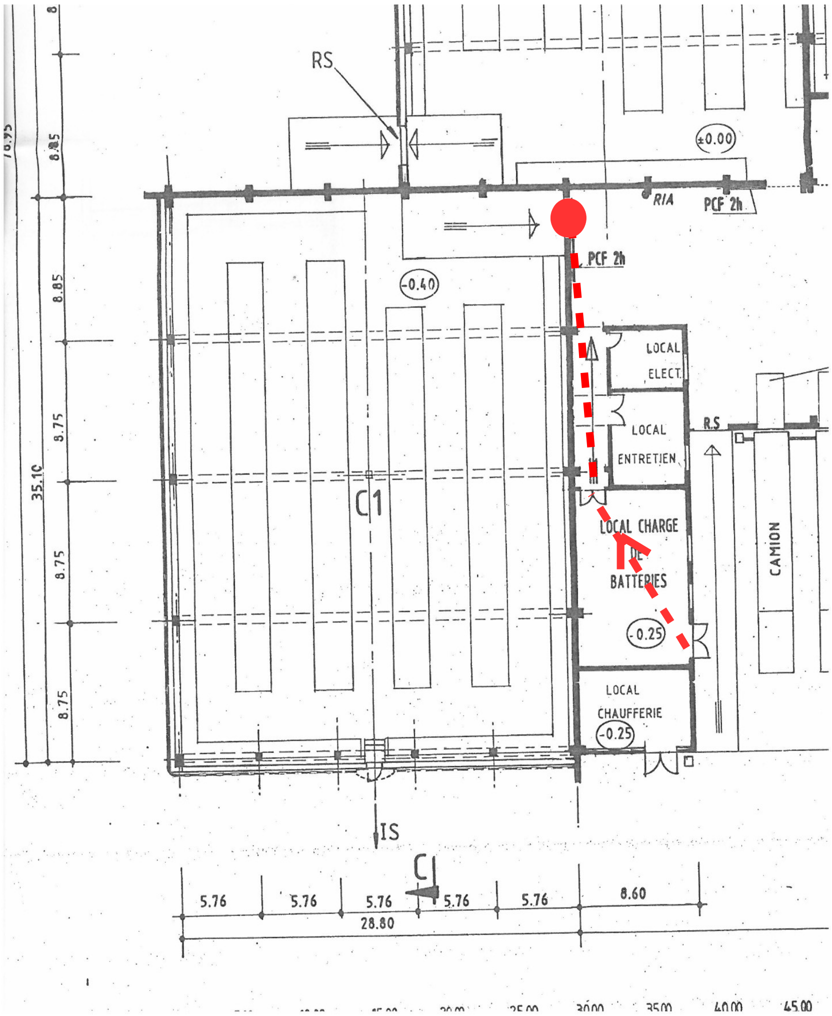
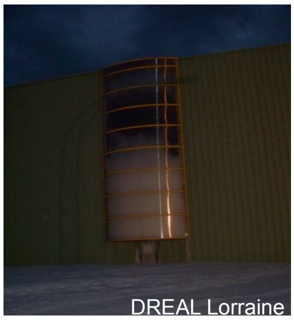


Figure 5 : Path followed by the three fire-fighter investigation team (ARR)

This hypothesis was confirmed by the fact that a glass column on the side of the cell made it possible to observe that at the time the emergency crew arrived, Cell 1 was entirely filled. An hour later however, the same glass enclosure revealed a foam height reaching about 60%: due to pressure generated by this volume of foam, the foam itself had settled, especially closer to the floor and its bulk had decreased. Moreover, the foam that filled the access corridor must have escaped from the cell through wall seams since the cell door had remained properly closed. The foam therefore had to contain the smallest bubbles, hence the lowest bulk. Even though no sampling conducted at the time could prove it, experts considered that the trio of fire-fighters on reconnaissance were indeed facing a foam displaying a bulk significantly less than 80, making it a low bulk foam.



ACTIONS TAKEN

Administrative actions

Within 72 hours, the Inspection Authorities for Classified Facilities ordered the site operator to halt all incoming deliveries of hazardous substances, given the degraded safety conditions at the warehouse. Incoming non-hazardous substances were still accepted, as were outgoing shipments of both hazardous and non-hazardous materials. The local governement issued an emergency measure requiring the operator to install a round-the-clock foam injection system in order to compensate the loss of a stationary pump. The authorisation to resume all site operations was granted to the operator 40 days later, under his full responsibility and subject to strict compliance with the following provisions:

- replenishment of the emulsifier stock;
- installation of a mobile motorised pump offering characteristics similar to the previous pump;
- ban on activating automatic injection as long as the origin of these aberrant detections remained undetermined;
- site surveillance outside of working hours to immediately initiate manual foam injection, if needed;
- special training sessions organised for both the warehouse company and surveillance firm on how to proceed with a manual foam injection response.

Authorities also sent a correspondence to all operators of "upper tier Seveso" rated facilities within the administrative area requesting them to ensure that, in the case of offsite video surveillance, the instructions furnished actually listed the local fire station emergency phone number and not only the national fire emergency number ("18").

Technical actions

Warehouse management restored the facility's safety equipment (pump replacement, replenishment of emulsifier stock, repairs to the fire detection system) and modified the set of instructions provided to the surveillance firm in specifying the local emergency fire services number (a 10-digit number and not the national fire emergency number "18"). The step was also taken to clearly note on the stock status tracking document dedicated to storage cells that the number appearing on the cover of each product family in storage was indeed the corresponding ICPE category number.

LESSONS LEARNT

This accident served to draw the following lessons:

The importance of acknowledging hazards to first responders (internal or external) by using foam

High bulk foam may create certain hazards depending on its application conditions. In a closed building with high ceilings, the foam formed by the extinction system might display significantly less bulk than expected. In turn, this low bulk can cause the following hazards for individuals present inside:

- decrease of some senses needed to carry out their action or survive in this environment (sight, hearing);
- substantial viscosity impeding all types of movement;
- excess consumption of air and penetration of foam inside the mask for those wearing insulated self-breathing apparatuses;
- formation of a film capable of asphyxiation when inhaling this foam.

The design of manual triggers for automatic extinction may prove to be vulnerable (due to a lack of redundancies)

Placing the warehouse in safe operations mode was contingent upon a simultaneous fire detection by two distinct detectors, which protects against unwanted foam injection resulting in operating losses for the warehouse. Yet this principle of detection redundancy had not been in effect for manual triggers since just a single detection with this type of trigger, even when activated by an electrical fault and not a deliberate employee manoeuvre, was sufficient to initiate the safety action sequence, including automatic foam extinction. For this type of design therefore, each manual trigger constituted a potential source of malfunction within the automatic extinction chain.

The potential risk of mistaking ICPE category numbers used by the operator with the hazardous substance transport numbers more familiar to emergency services personnel

Knowledge of ICPE regulations is a critical part of the curriculum of most local fire-fighting officers in France. Yet this content is not taught during the training program for other categories of fire-fighters, including those making up the majority of response teams, even though their education calls for an extensive coverage of regulations on transporting hazardous substances, with special emphasis on the meaning of safety plates affixed to vehicles ("RTN" module:

Technological and Natural Risks). In both of these regulations, 4-digit numbers were primarily used, often without specifying the substance name or corresponding ICPE activity (see Fig. 4, right).

As such, the ICPE category number used by an industrial operator may be interpreted by emergency services as a UN number assigned to the transport of hazardous substances. The issue here however is that the hazards associated with substances identified by the UN code and those referenced in the French ICPE activity of the same number are, most of the time, very different. In an emergency situation, this source of confusion may lead to misunderstanding, in turn prompting inappropriate actions on the part of first responders, as aptly illustrated by the accident presented herein.

The importance of providing precise instructions to offsite surveillance firms

The warehouse operator had requested his video surveillance firm, located in a different area, to notify emergency services on their own in the event of fire outbreak, by dialling the number "18", which simply relays to the call desk of the caller's local fire services.

If the surveillance firm is not based in the same area as the facility operator, which was the case here, it is not connected with the appropriate local fire service, which delays an effective response. When drafting the instructions and response sheets for emergency situations, the operator must provide the subcontractor with the actual (10-digit for France) phone number of local fire services for the site location.

In conclusion, it was recommended to:

- determine whether, in light of the safety report, it was acceptable for manual triggers to be able, in the event of simple malfunction, to activate automatic safety devices; should the answer be no, and especially if the safety of employees or first responders was at risk or economic losses deemed too extensive, then it would be necessary to back up both the manual triggers and the cables transmitting signals to the programmable safety controller;
- ban access to cells filled with foam; nonetheless, employees required to violate the ban in order to gain entry, in particular to implement measures necessary to destroy the foam, must imperatively be attached to a life line;
- ensure that inventory report documents made available to emergency services clearly underscore the fact that the numbers used are those of the environmental authority headings (if any, e.g. coloured insert on the front or upper part of the document, addition of the mention "ICPE No." in the number column). This consideration must also be regularly pointed out by the operator during interactions with local fire service representatives, e.g. when conducting joint drills or preparing / updating the external emergency plan for Seveso-rated facilities;
- verify that the instructions and emergency response sheets provided to personnel assigned to monitor the site and sound the alarm (watchman's quarters, surveillance firm and/or video monitoring unit) show the local phone number of the main fire station corresponding to the site location, Moreover, it is essential that these individuals realise the need to call this number in case of emergency and not the national (18) or European emergency number (112).

Theme 3

Pyrotechnics :

why did the technician fail to follow the procedure ?

Pyrotechnics: Why did the technician fail to follow the procedure?

In the pyrotechnics sector, 12% of accidents are associated with inappropriate human handling, primarily failure to follow procedures (since the ARIA database was created, 132 accidents fall into this category out of a total sample of 1076). This number sparks interest, especially given the likelihood that the actual number is even higher since the causes of a large proportion of accidents remain unknown. The recurrence of situations involving procedural non-compliance in pyrotechnic activities is all the more surprising knowing that this sector imposes lengthy procedures due to the potential fatal consequences for the most minor of infringements. These rules and guidelines are thus in place to protect technicians' lives!
Several types of procedural non-compliance can be distinguished: those due to error (unintentional actions) and those due to deliberate action, i.e. violations. The first ones (oversight, clumsiness, confusion, etc.) are by far the most common. However, the two accidents presented during the "Pyrotechnics" session at the IMPEL 2015 seminar illustrate the second aspect, namely wilful procedural infraction (proceeding with an unscheduled action to cut away a contaminated pipe; non-secured actions taken when transferring pyrotechnic products). Such actions are the focus of the present fact sheet.
Based on actual case studies, the objective is first to present typical set-ups in which technicians wind up knowingly circumventing procedures and then investigate the associated underlying causes across the range of context described.

1. Three typical situations involving procedural violation

When committing a violation, the technician is knowingly breaking a rule, i.e. he is fully aware of engaging in an unauthorised action at the very point in time he is undertaking such an initiative. We therefore exclude those cases where the procedural non-compliance occurs subsequent to an unintentional manoeuvre (oversight, handling error, interpretation error, confusion, clumsiness).
A procedural violation may take several forms:

- The non execution of a required action, such as inserting bags of pyrotechnic wastes into anoven without first opening and inspecting their contents;

- The incorrect execution of a required action, such as placing an excessive quantity of explosives into burn-out kilns, or a handling step conducted by a single technician instead of two during normal operations resulting in a dropped vessel;

- The execution of a non-required action, such as the forced restart of equipment that had been considered faulty, or the completion of an unscheduled operation.

Based on findings from accident studies, three typical configurations arise in which a pyrotechnic installation technician may be led to circumvent procedures:

1. To facilitate his task; the objective might be to save time in order to complete an assignment more quickly, e.g. by exceeding product quantities specified for a given workstation, or else to avoid confrontation with a supervisor. According to this configuration, the technician does things "his way" and places other concerns above compliance with safety rules.

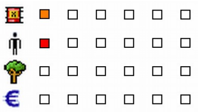
2. To seek problem resolution, often in acting alone and sometimes in the place of others, instead of securing the installation and notifying the supervisor. In all these cases, the technician is indeed taking his job seriously (i.e. trying to resolve an abnormal situation as quickly as possible), but the outcome of his initiative fails to meet expectations. Rather than producing the anticipated remedial effect, the technician's improvised action causes an accidental drift, in many instances by bringing mechanical energy in the presence of highly reactive products (e.g. the technician opening a machine that has stopped and pulling on some parts in order to restart it).

3. To respond to demands imposed by the organisation, which most frequently call for respecting time constraints or meeting objectives.

Behind the violations themselves, which constitute the initial accident symptoms, are deeper root causes. They may be related to the technician and his physical state (e.g. fatigue, overconfidence) but also to his affiliated organisation (working conditions, risk management). In general, a combination of these two factors is at play, whereby an inappropriate organisational procedure sets the stage for a technician to break an operating rule.

2. Case of a technician looking to take shortcuts, call his own shots

Example of an accident corresponding to this case



ARIA 22504 - 18 May 2001 - 09 - MAZERES

In a fireworks factory, a potassium nitrate and aluminium-based pyrotechnic compound under study exploded as it was being destroyed. Chemical instability caused an exothermic decomposition and explosion. The accident resulted in 3 slight injuries (burns and auditory trauma), yet the consequences could have been much worse.

Even though the technician was experienced (10 years in the trade) and the operating protocols tried and tested for 20 years, several procedural errors and compliance breaches have been reported, namely:

1) Water, which undermines compound stability, was used as a wetting agent instead of a water/alcohol mix.

2) The procedure called for immediate destruction of all study compounds: delaying this action increased the likelihood of an accident (compound decomposition time).

3) 10 kg of compound were prepared for destruction, whereas the procedure had stipulated fractioning into 2.5 kg jars. This breach exacerbated the accident effects and consequences.

The factory operator disciplined the technician for failing to follow instructions. He conducted a review of breakdowns in both the safety management system and the ability to keep technicians in a state of "permanent vigilance". The quarterly awareness session attended by technicians, as imposed by the regulation and implemented on-site, was incapable, in this specific case, to avoid the occurrence of a phenomenon of habituation.

Analysis of root causes

The technician who decides to ignore procedures when executing an assigned task is frequently unsatisfied about imposed working conditions. Indeed, problems involving workstation ergonomics, directly associated with a suboptimal selection of equipment and processes, commonly instigate inappropriate behaviour. For example, an installation set-up that complicates cleaning could promptly assigned personnel to do a hasty job in order to avoid all the extra effort required.

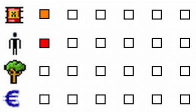
The organisation implemented in terms of guidelines and procedures might also be blamed. Existing procedures, whose content still seems to be relevant, may be applied inadequately or ignored altogether by technicians for various reasons. Accident studies reveal situations in which procedures are perceived as too burdensome and restrictive. Other cases point difficulties in procedural implementation due to instructions unavailable in the technicians' mother language, or only provided orally or else posted in the wrong zone. Procedural simplification and the creation of more "practical" tools, e.g. instituting a checklist of verifications to be carried out before start-up, are some actions designed to remedy this problem. A coordination process might also be introduced to optimise procedures and facilitate technician acceptance.
Inadequate training is another frequently cited cause, since technicians with little awareness of the sensitivity of products being handled might circumvent rules without realising the seriousness of their action and its potential consequences. However, when the training offered technicians is substandard, this tends to reflect that the global host organisation's safety culture is severely lacking. It must then be considered that the corrective action of "reminding staff to follow instructions" or "improve their awareness", as often practiced by facility operators, will only be effective if accompanied by a wholesale change in attitude among the entire organisation.

On the other hand, it is important to ensure that habits specific to an individual do not undermine the efforts expended by the whole organisation as regards risk-related training. A seemingly rigorous training process (with regular refresher courses) and the existence of proven procedures actually fall short of preventing rule violations by technicians if the "human factor" has not been fully taken into account. As displayed in ARIA accident 22504 above, an experienced technician's overconfidence can lead to taking liberties with posted instructions and executing actions not specifically stated in the company's operating rules.
This context obviously highlights issues of workplace organisation and supervision. The accident described above reveals the drifts arising from insufficient oversight. Such management problems are also illustrated in ARIA accident 45545 presented at the IMPEL 2015 seminar: the absence on the day of the accident of several supervisors, who would have been able to validate the protocol, was probably one of the factors resulting in technicians undertaking an ill-advised initiative.
These shortcomings in workplace organisation and supervision go hand in hand with flawed verification procedures. A verification policy that is poorly designed or not adapted to the existing risks acts as a disincentive for technicians to follow the rules. As an example, the inability to ensure that quantities used

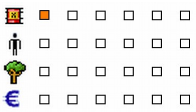
match workstation authorisations might lead technicians, as in the case above, to pay scant attention to the indicated values, no matter how critical they may be when working in contact with pyrotechnic substances.

3. Case of a technician who takes it upon himself to solve a problem

Examples of accidents corresponding to this case



ARIA 31905 - 24 February 2005 - 45 - LA FERTE-SAINT-AUBIN
In an explosives factory, a production technician was periodically cleaning the crimping devices of detonators using a rag soaked in alcohol. During this operation and the follow-up visual inspection, he noticed a number of metal burrs on the punch. **Remembering how the explosives expert and adjuster handled this situation, he disassembled the punch-holder unit using dedicated cleaning equipment. A pop (detonation) occurred when removing the metal parts.** Friction had caused the reaction when cleaning metal burrs fouled by a primary explosive (detonators containing 25 mg of dextrinated lead azide and 50 mg of reinforcing compound). The technician escaped with just a few slight wounds to the face and finger since he was wearing safety glasses and ear plugs. **Despite the instructions, operating protocol, training and his experience, this technician still performed an unplanned task without assessing the hazard.** Usually, such operations are carried out alone behind a screen by either the adjuster or explosives specialist, and only after foreman approval and chemical neutralisation of the explosive.



ARIA 24923 - 26 September 2002 - 65 - TARBES
During initiator loading with a potassium perchlorate and zirconium-based pyrotechnic compound, 110 g of compound reacted in the hopper. The hopper's cover pin was ejected in blasting off the cover.
The automatic cycle of the machine was stopped after detecting a settling defect. **The technician, believing that the storage cell had not been filled properly, restarted the cycle, which led to a double filling.** The friction generated by this overfilling of the cell triggered the initiation. Subsequent analysis revealed that the compressive force control sensor had been inoperable since a prior incident (ARIA 24922).
The plant operator modified the machine and informed personnel about the need to warn supervisors whenever an anomaly is detected, in order to analyse the situation before any resumption of activity. The operator also implemented an inspection procedure for safety devices like sensors after each reported incident.

Analysis of root causes

When a technician takes initiative in the aim of resolving an abnormal situation on his own, he is showing a desire to "focus on the most urgent" even if it means overlooking basic safety principles. This type of phenomenon is also on display in the example of a management employee who decides to take action despite poor knowledge of the installations and a role without direct responsibility over technical operations, and finally commits an error while attempting problem resolution. Such response to exceptional situation raises questions over the extent of employee awareness about risks incurred and how risks are managed as part of the corporate culture. Has the organisation been efficient enough in its effort to build risk awareness? Are the models proposed by managers consistent with the expected safety attitude? Are some goals actually at odds with the implications of taking a more cautious approach (e.g. productive pressure)?

In building risk awareness, it must be ensured that the training offered to hands-on personnel is adapted with respect to both its content (inclusion of explanations on the behaviour to adopt when confronted with an atypical situation, e.g. malfunction, faulty classification) and its dissemination to technicians (necessity of refresher courses or regular "review sessions" to enhance assimilation of the material). The two accidents summarised above illustrate the drifts tied to inadequate training: error in identifying the type of fault occurring at an installation, failure to implement the supervisor's alarm procedure when an anomaly arises.

Organisational deficiencies in the area of risk identification are associated with incomplete procedures that give technicians too much leeway regarding the behaviour to adopt: ARIA accident 24923 reveals that, prior to this incident, no formalised procedure had required the systematic verification of key safety-related elements following an incident.
Along the same lines as the case described in Section 2 above, insufficient training and failure to identify risks may rise a technician's overconfidence or lack of risk awareness and moreover let him believe in his ability to manage a situation on his own, no matter how complex, e.g. in repeating what had been witnessed previously by fellow technicians (see ARIA accident 31905).
The two examples cited above once again reveal the effect of a poor working organisation with insufficient oversight and supervision.

4. Case of a technician under pressure

Example of an accident corresponding to this case

ARIA 20502 - 15 February 2000 - 83 - TOULON
When handling a missile launcher, a missile fell 0.6 m, yet this did not trigger any pyrotechnic activation. **The forklift operator was using an inappropriate vehicle in order to save time.** He raised the missile too high off the ground, which caused the fall. Other anomalies were also recorded: the container had not been properly marked; the crate was blue (i.e. the colour used for drill exercise equipment) despite the missile not being inert. The missile was only slightly damaged and able to be restored. The operator re-issued the operating guidelines in addition to holding quarterly information sessions, as required by the decree of 28 September 1979 related to the protection of workers in the pyrotechnics industry.

Analysis of root causes

Situations involving procedural violations by technicians subjected to pressure are commonly encountered in the realm of handling operations, as illustrated by ARIA accident 20502 above, as well as by the accident that occurred in Italy and presented at the IMPEL 2015 seminar: due to a peak in seasonal activity, employees at a fireworks plant acted hastily and without following the full set of safety rules.

A worsening psychosocial environment might also constitute a deep-rooted cause of certain procedural violations: excess workload (than can prompt a technician to assume responsibility for a task outside his assigned mission, in a move to "help colleagues", and thereby lead him to commit an error), or stress tied to extreme operating constraints or scheduling demands. Along these lines, it is worthwhile to note that an excessive workload often becomes a chronic problem, e.g. a return every July for recreational fireworks manufacturers.

While the number of known cases clearly pointing to excessive pressure on technicians as the underlying accident cause remains quite small, these cases still provide instructive value. Such a configuration is in fact likely to be present in a larger number of cases than it appears at first glance. It should nonetheless be noted that problems of psychosocial workplace conditions more often act as an exacerbating factor for other deep-rooted causes (e.g. risk identification, workplace organisation).

Conclusion

Technicians' awareness of the importance of procedural compliance is critical, if merely for their own safety: breaches like neglecting to wear individual protective gear or failure to abide by the "in case of accident" response protocols can worsen the human consequences of accidents. In the pyrotechnics industry, even more than in other sectors, anything not specifically authorised is strictly prohibited. The organisation is responsible for implementing the right resources to avoid these operational drifts via a multifaceted strategy, whereby a purely procedural and organisational dimension must be complemented by a robust "safety culture", i.e. raising risk awareness coupled with promoting a prudent and precautionary attitude in any situation on the part of technicians.

Pneumatic explosion during an intervention on a pipe at a pyrotechnic plant

30 July 2014

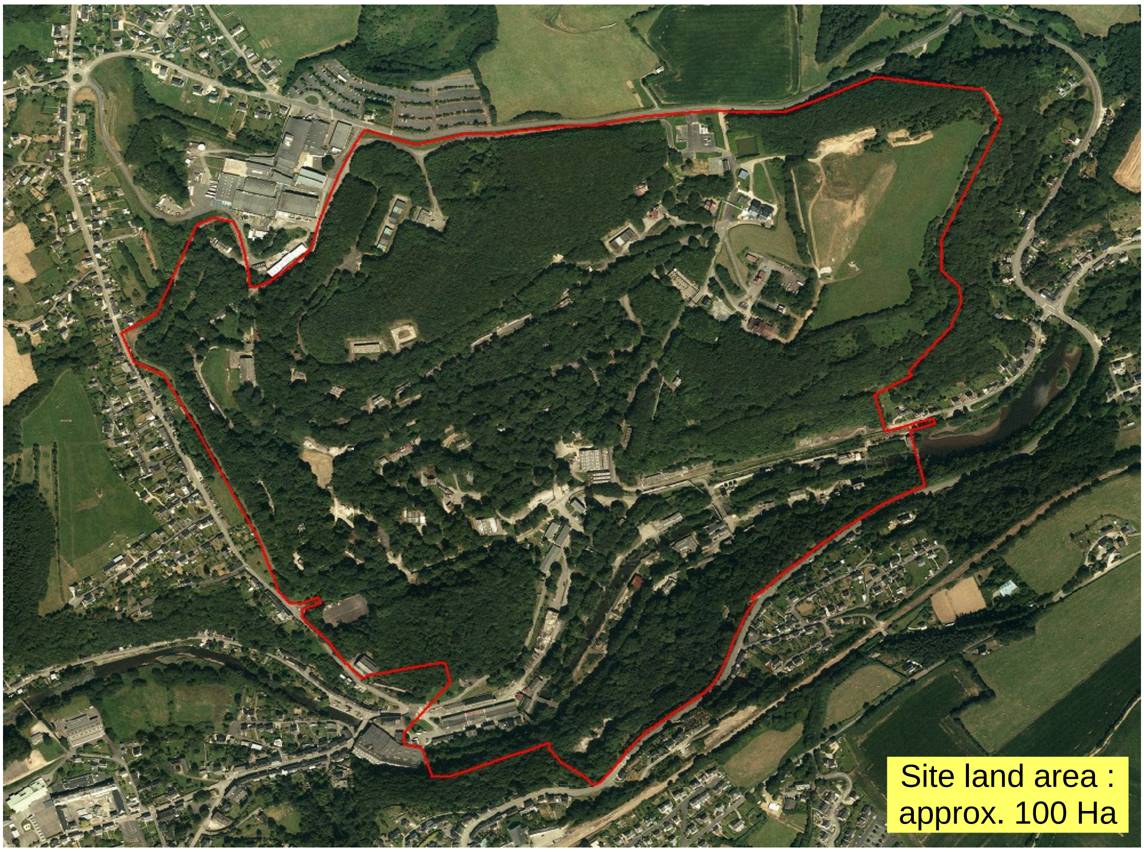
Pont de Buis (Finistère)

FRANCE

Pyrotechnics
Pneumatic explosion
Organisation / Procedures

THE FACILITIES INVOLVED

The site:



The facility was producing:

- primarily powders for hunting and sport shooting;
- but also products for law enforcement (tear gas grenades, smoke grenades, explosive cartridges, etc.), plastic materials and composites.

On-site activity included the storage and shipment of finished products as well as the destruction of pyrotechnic waste.

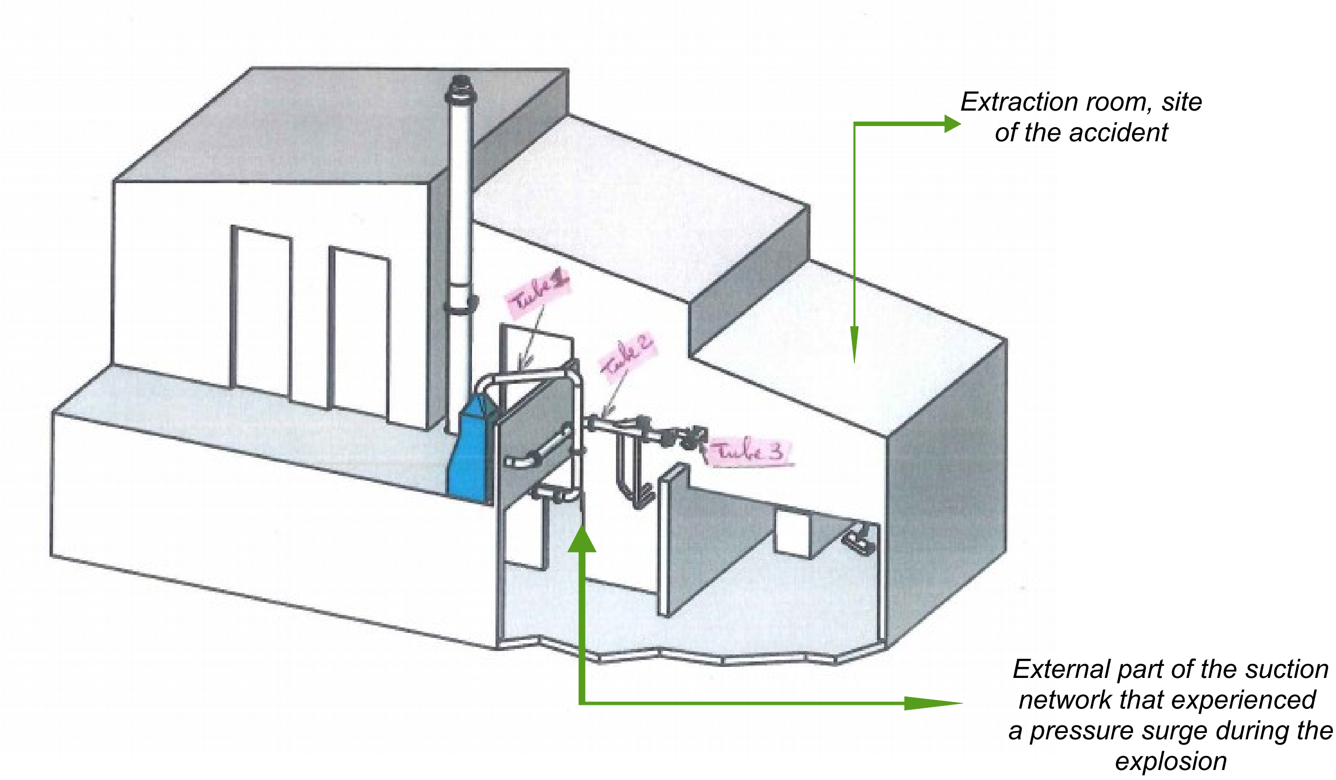
The facility was under the autorisation regime with easements, as prescribed under Book V of the Environmental Code, and moreover falling within the "upper tier" category of the Seveso II Directive.

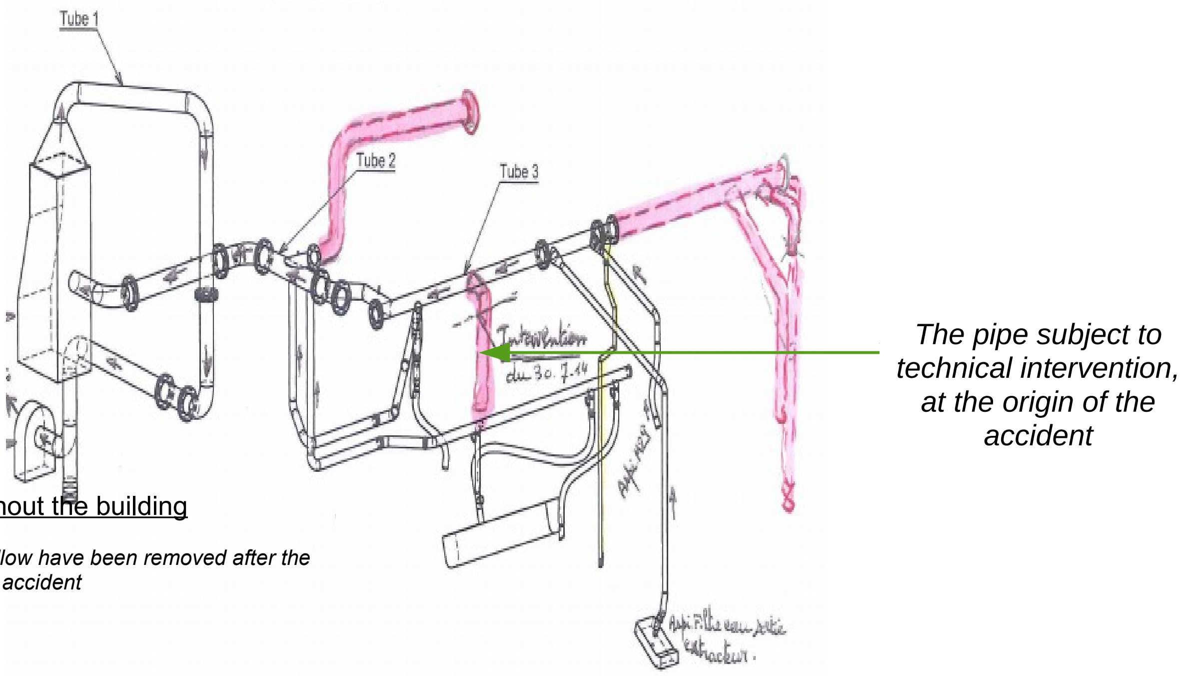
The involved unit:

The installation involved was one of the powder production units. A double-screw extruder, fitted with a double worm gear, made it possible to continuously perform in just a single operation:

- the assembly and mixing of raw materials;
- their extrusion via a dedicated line;
- the cut-out step to obtain powder.

The accident occurred inside the "extractor" room located on the ground floor of the production workshop. This room was equipped with machinery for extracting the solvents contained in the powders output by the double-screw extruder operating on the floor above. This extraction entailed washing with hot water circulating upstream in a worm gear. The solvent-laden water recovered was then channelled to a distillation unit for solvent regeneration. In conjunction with this step, the air filled with volatile organic compounds (VOC) was also collected by a suction network for distillation treatment prior to discharge. This network wound up at the origin of the accident.





View without the building

The pipes in red and yellow have been removed after the accident

THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

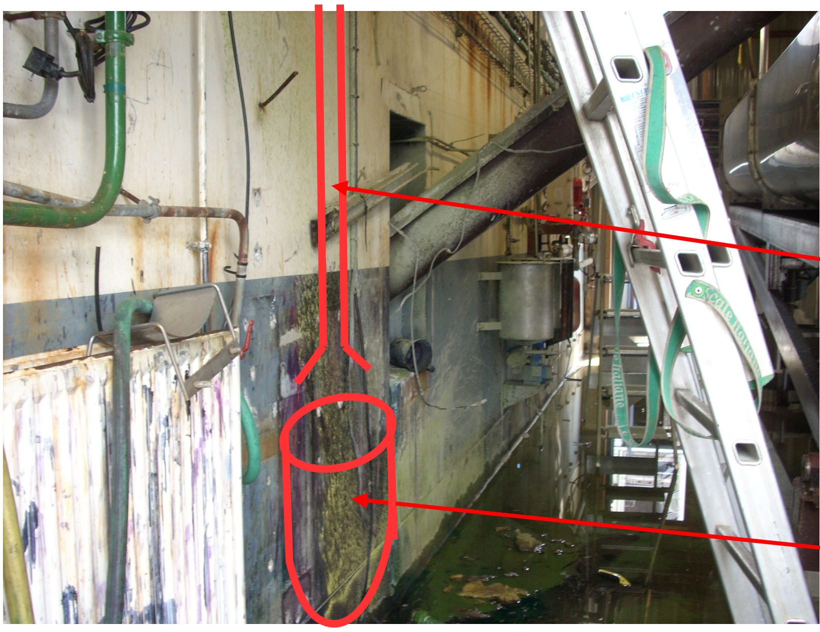
The accident:

The accident occurred during the 3 weeks annual maintenance period. This down period was dedicated to performing various maintenance operations and repairs.

The accident happened as an intervention was conducted with the purpose of modifying the powder dye installation: a dye tank was to be replaced and then disassembled.

Taking the former dye tank off-line rendered inoperable the air extraction network duct at the site of the tank. In order to definitively remove this ductwork, a technician assigned to the powder manufacturing workshop began to cut away with a metal saw the particular section of pipe (a vertical, 80 mm diameter stainless steel tube). During this operation, a second technician was tasked with flooding both the saw blade and pipe from the outside. These two technicians were positioned approx. 2 meters above ground on ladders placed on both sides of the pipe being sawed.

Around 4 pm, **this pipe experienced a pneumatic burst.**
The explosion did not spark a fire or trigger a secondary explosion. The building was cooled by deploying the company's water reserves.



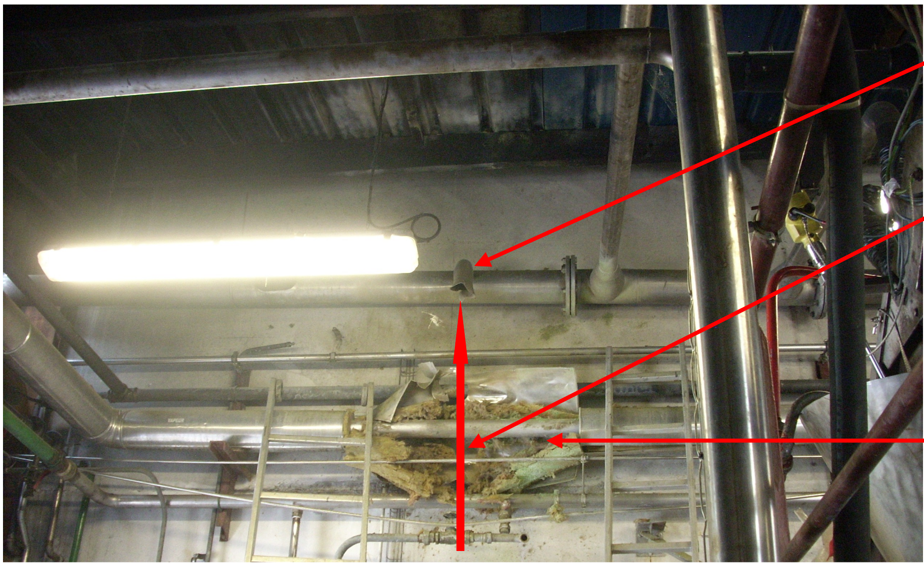
Location of the suction pipe that was rendered inoperable, i.e. the origin of this accident

Location of the former dye tank (under the pipe at the origin of the explosion)

The consequences of the accident:

Material consequences:

The powerful pressure surge associated with the explosion led to considerable metal debris being blasted within the room, as well as ruptures at several vulnerable parts of the suction network. In addition, metal foil installed on flanges was ripped open.
These material consequences were limited to the equipment involved in initiating the event and other machinery located immediately adjacent.

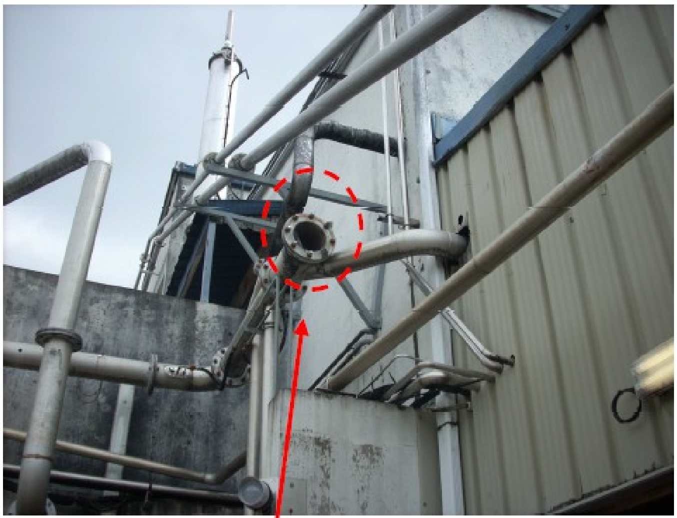


Remainder of the pipe torn off by the explosion

Location of the stripped "idle" pipe section

Damage caused by the explosion on heat insulation of a nearby pipe

The portion of pipe damaged by the explosion was an "empty" conduit from a larger network responsible for collecting VOC-laden air in various zones of the workshop.



Plugs and/or foil present on the suction network that had opened subsequent to the pressure surge generated by the explosion

Human consequences:

The three technicians present in the utility room at the time of the event (two employees, one temp worker) were seriously injured and had to be hospitalised. The two working on ladders sustained facial burns from the flash and pneumatic pipe burst. The third victim, standing on the floor, was struck on the arm by flying metal fragments and these injuries required amputation.

European scale of industrial accidents:

By applying the rating rules applicable to the 18 parameters of the scale officially adopted in February 1994 by the Member States' Competent Authority Committee for implementing the 'SEVESO' Directive on handling hazardous substances and in light of available information, this accident can be characterised by the four following indexes:

Dangerous materials released	■ □ □ □ □ □
Human and social consequences	■ ■ □ □ □ □
Environmental consequences	□ □ □ □ □ □
Economic consequences	□ □ □ □ □ □

The index corresponds to hazardous substances released. Level "1" was reached since the accident involved pyrotechnic substances (quantity of explosive substance contributing to the explosion < 0.1 tonne of TNT equivalent).

The index corresponds to human and social consequences; it was scored a "2" due to the fact the accident caused 3 serious injuries (level "2" definition: presence of 2 to 5 serious injuries).

The parameters composing these indexes and their rating methodology are available on the Web page: http://www.aria.developpement-durable.gouv.fr

THE ORIGIN, CAUSES AND CIRCUMSTANCES OF THE ACCIDENT

Primary cause of a technical nature

Pyrotechnic dust residue (a yellowish substance with powdery texture) was present on the metal debris of the stripped pipe (found on the floor of the workshop and outside the building, along the path of the foil that had been ripped apart). These observations indicated that **the pipe had not been adequately washed** during preliminary rinsing steps.

Metal debris, from the pipe blasted by the explosion, found on the floor. The picture on the left shows residue from pyrotechnic dust (yellowish) covering the inner pipe wall.

The fire most likely broke out due to ignition of this powder residue and/or pyrotechnic dust accumulated inside the pipe. This build-up was correlated with the **heating produced by friction of the metal saw blade on the stainless steel suction pipe (hotspot)**.

Root causes of human and organisational nature

A procedure carried out in violation of accepted protocol

According to the plant operator, the extraction pipe cut-out procedure had not been scheduled during the plant's annual closure. It was decided, on the spur of the moment, by manufacturing workshop technicians assigned to perform the dye installation modification. No hot work permit had been issued.

The applicable procedures for supervising works capable of creating hazards stipulated that:

- In the case of repair work on fouled hollow bodies:

  "When cutting out a hollow body that had contained pyrotechnic products (powder, dust, nitrocellulose, etc.) or solvents, or when suspecting their presence, the use of a pipe cutter or tools capable of generating a hotspot must systematically be specified in a hot work permit.";

- The hot work permit was to be signed by the job supervisor, the repair technician and at least one management representative.

When cutting the portion of pipe rendered inoperable, **several violations were committed by undertaking this procedure :**

- **Despite not having been scheduled;**
- **Lacking proper approvals or hot work permit;**
- **Without any preliminary validation of working conditions by a supervisor.**

The failure to procure a hot work permit was the root cause of this accident since it led to the absence of:

- A validation of operating conditions,
- The implementation of compensatory measures to mitigate the potential presence of pyrotechnic residue in the pipe.

It should be noted that the use of a metal saw had not been strictly prohibited. The dedicated procedure had simply stated that: "*Mechanical disassembly must systematically be favoured over any intended cutting operation.*" The objective behind issuance of a hot work permit that incorporates safety measures and special prescriptions is indeed to oversee situations in which the use of a tool capable of creating a hotspot, e.g. a metal saw, cannot be avoided. Such was the case here due to the vertical pipe configuration, placed against the wall: it was technically impossible to introduce a pipe cutter, which proceeds by rotating around the element to be cut.

The identifiable root cause at first glance: the human factor

According to the plant operator, the manufacturing workshop technicians, who took the initiative of removing the idle pipe section of the suction network, were indeed experienced and knew the building layout very well. Their seniority probably led to a **feeling of overconfidence** as regards their handling of the situation, prompting them to waive the rules in the aim of improving the results of their intervention.

Yet beyond these personal factors, procedural non-compliance can be traced to a series of organisational breakdowns.

An insufficient presence of supervisors during the annual maintenance period

On the day of the accident, the facility director, his deputy, the head of the safety department and the industrial director were all on holiday. Only the on-call manager was present at the site during a technical maintenance period that nonetheless featured a number of non-standard procedures. This **inadequate oversight** could have led technicians to act solo, without the possibility of a streamlined validation from superiors.

Inaccuracies in the official instructions and procedures

The presence of dust in the given pipe raises questions about the pyrotechnic decontamination protocol. The published **procedure outlining cleaning** (SE09: "Procedure for handling contaminated equipment") actually **remained quite qualitative**, simply noting that: *"Contaminated equipment must be decontaminated as much as possible."* The operating protocol should definitely have been explicit about guiding technicians in their tasks.
Article 8 of the Prefectoral order issued on 25 July 2003 relative to hot work permits also failed to define cleaning quality criteria. It merely prescribed: *"When works are carried out in a zone displaying major risks, the first step consists of completely shutting down and draining installations in the designated zone, along with cleaning and degassing the devices to be repaired plus a preliminary verification of a non-explosive atmosphere."*
In addition to the cleaning steps themselves, arises the question of the means for verifying cleaning efficiency. **No formalised procedure actually imposed verification prior to any works or addressed the state of cleanliness of pipes** that had contained pyrotechnic products. This shortcoming suggests insufficient recognition of the risks associated with such a configuration on the part of the company.

This failure to fully acknowledge risks was reflected by deficiencies found in other procedures. Such was the case as well regarding the sprinkling introduced during the cut-out operation. **No instructions had been written on the flooding methods or equipment to use.** This operation however is a vital compensatory measure as soon as a cut-out procedure needs to be performed with a tool capable of generating a hotspot and especially in the absence of any guarantees on the pipe's state of cleanliness.
In the present case, the technicians, who were probably aware that the cleaning might not be exemplary, set up a means for flooding. Yet in all likelihood, they had not been trained in this particular step, which had never been formalised. They performed sprinkling from the exterior as well as interior (via the upper portion of the pipe to be removed), while holding a simple sprinkler hose. This approach proved incapable of wetting and eliminating the powder residue that had dried inside the pipe (the installations had been idle for six days and the ambient temperature was around 23°C).

A non-efficient training process

A training programme must normally serve to transfer key knowledge required to carry out the various tasks technicians were assigned under optimal safety conditions. Formalised instruction is necessary to ensure course content is being transmitted to the entire workforce. The safety instructions associated with "cutting out a hollow body" were not specified in the hot work permit specific to each operation of this type. Consequently, the instructions were not incorporated into the general guidance procedures, which in turn hindered their recognition during the employee training process. The initiative taken by technicians was thus a manifestation of a flaw in the company's training strategy. It is therefore recommended to insert into the facility's safety management system some general safety principles applicable to hollow body cut-out operations.

Debatable choices regarding certain equipment

The selection of some equipment proved to be unwise. For instance, the suction network ducts were hard to inspect and access. This **ergonomic problem** relative to the installations obviously constituted an obstacle to a high-quality cleaning of the ducts. The remedial measures proposed by the site operator (as detailed in the "Actions taken" section below) demonstrated his awareness of this fact. As an example, it would have been possible to rely on flange couplings rather than welded couplings.
The sprinkling systems used during pipe cut-out also revealed that technical resources intended to guarantee safety during repairs conducted in the pyrotechnic zone had not been allocated. The absence of suitable instruments led technicians to use a simple sprinkler hose whose pressure was most likely insufficient to reach all zones of the internal faces of the pipe wall. An apparatus with a higher flow rate and pressure would certainly have been more efficient.

Inadequate attention paid to experience feedback

In December 2004, an accident (ARIA 28707) caused by a similar pipe cutting operation occurred at the same site. This event had prompted the operator to revise the work permits issuance procedure by adding a heading for "hollow body cut-outs". It had also led to systematically requiring a hot work permit for any works suspected of involving a hotspot or heating that were to be carried out in a contaminated environment. Implementation of these **corrective measures** fell short however of preventing the occurrence of this new event since the **operator failed to sustain their application over the long term**.

In sum, a substandard safety culture

On the whole, inappropriate or incomplete procedures, ineffective technician training or managerial lapses during down periods reflect a poor company-wide safety culture. **The operator did not deploy the full set of proper resources to ensure that staff could comply with procedures and that on-site maintenance operations could be successfully conducted.**

As pointed out by the Inspector of Classified Facilities, the operator failed to respect the prescriptions cited in Article 7 of the order adopted on 10 May 2000, and modified thereafter, relative to the safety management system applicable to installations capable of causing major accidents inside a SEVESO-designated facility. This article moreover stipulates that:

"*[…] The operator is to implement all procedures and actions outlined in the safety management system. […] The operator is also to allocate resources appropriate to this system and ensure its effective operations. […]*"

ACTIONS TAKEN

Subsequent to this accident, all subcontracted works and repairs were suspended and factory premises underwent clean-up and decontamination. Site activity was resumed on 20 August 2014, or three weeks after the accident had occurred.

The Inspection Authorities for Classified Facilities recorded the regulatory infractions and breaches at the origin of this accident. A formal notification and infringement statement were issued against the operator.

Several corrective measures were adopted by the operator, either of his own volition or imposed by the Classified Facilities Inspector.

Organisational measures:

- *Regarding the breaches in terms of workplace organisation and supervision:*

The Inspection Authorities requested that the operator consolidate the set of conditions relative to continuous supervision and management during holiday and maintenance periods. In response, the operator committed to reinforcing the existing organisation, notably by introducing a **daily gathering of all maintenance personnel with supervisors to discuss currently scheduled tasks**. Moreover, a policy was adopted to have at least two supervisors present instead of just one during all phases of down time for technical repairs.

- *Regarding technicians' failure to comply with procedures:*

The training courses offered to personnel were to include a **module relative to human behaviour** and the means employed to avoid "errors". Following the accident and before restarting the installations, a memorandum was circulated to the entire workforce on the importance of complying with procedures.

- *Regarding the inadequate cleaning of installations:*

The operator extended and consolidated its dedicated procedure. **The cleaning guideline would contain a checklist** detailing, workshop by workshop, the sequence of preliminary washing operations to be performed depending on the specific situation (index change, weekly cleaning, installation shutdown). A fact sheet recorded the successful execution of these operations and was submitted to a manager for final validation. These preliminary measures allowed the manager responsible for the validation step to authorise or reject subsequent works. This modified order, with a double validation required by both technician and management prior repairs, was tested during the winter 2014 closure.

- *Regarding deficient sprinkling systems:*

The operator anticipated that a **"fire guard" could be named to ensure sprinkling** of the target zone during repair works. The fire-fighting lorry available to the operator could be present at the zone with all its accessories. A variable flow hose could also be placed into service to secure the work site as needed.

Technical measures:

- The pipes damaged by the explosion were repaired. **Rupture discs were installed on hinged flanges**; they could be manually opened to observe the inside of piping and verify the degree of cleaning efficiency.
- Broadly speaking, in order to limit the risks of pyrotechnic residue being present inside hollow bodies, the operator preferred **replacing former single-piece ducts with split stainless steel pipes** easy to maintain and inspect.
- The operator installed **detection equipment** to improve the identification of pyrotechnic substances within hollow bodies. A camera was purchased to visualise pipe interiors, and nitrocellulose detection products were also envisaged.

At the request of inspectors, the various **measures adopted relative to experience feedback from the 30 July 2014 event were formalised in procedures included in the plant's safety management system**. These procedures were the subject of a memorandum circulated to all personnel concerned.

Moreover, **the risk analysis associated with the facility's safety report was complemented** by incorporating the hazardous phenomena stemming from the potential presence of pyrotechnic residue in hollow bodies.

LESSONS LEARNT

Any repair work performed on an installation that over the course of its life cycle had been in direct contact with an active pyrotechnic substance must be closely monitored and undergo special precautions before, during and after the mission.

Before the mission:

- validation by the operations scheduling manager of pertinent execution conditions;
- drainage and pyrotechnic decontamination of machinery used during the mission;
- visual inspection of cleaning efficiency and decontamination using appropriate tools (endoscopes, cameras, etc.);
- verification of both the organisational and technical conditions of the mission by a safety manager;
- verification of the successful application of these dedicated procedures;
- verification that all mandatory documents framing and authorising the mission have been completed and signed by the competent authority.

During the mission:

- verification of sprinkling efficiency throughout the zone targeted by the mission;
- use of suitable equipment, if possible not needing to be placed too close to the installation itself;
- wearing of adequate protective gear;
- a work site layout to ensure an adapted mission protocol (no requirement to climb a ladder, optimised position, etc.).

After the mission:

- verification that the installation has been restored to good working order;
- completion of a mission acceptance / end of mission inspection in the presence of a designated manager;
- dissemination of lessons learned, if applicable, through experience feedback from the mission (difficulties encountered, technical advice, unexpected events, etc.).

Over the course of mission efforts:

On the whole, in pyrotechnic installations, efforts are to be aimed at achieving:

- a good level of coordination between management and technical staff based on regular exchanges, during which applicable risks and procedures are recalled and any difficulties in implementing procedures are aired;
- a sufficient level of managerial oversight, especially when conducting works, to provide optimal guidance should any unusual situation arise;
- an in-depth analysis of the experience feedback lessons and a top-down flow of information reaching technicians with the greatest chance of being concerned;
- the execution of daily actions to create and nurture a vigilant attitude inside the factory;
- an installation design that facilitates monitoring and regular maintenance operations;
- frequent training sessions covering the full set of risks associated with pyrotechnics, including those more insidious and deeply ingrained in human behaviour. The contents of these training modules must also emphasise the mandatory general procedures addressing safety.

Source of photographs on this document : DREAL Bretagne

Series of mass explosions in a fireworks plant

25 July 2013

Città Sant'Angelo

Italy

Pyrotechnics
Fireworks
Explosives
Domino effect
Victims
Material damages

THE FACILITIES INVOLVED

The site:

The accident happened in a fireworks plant. The plant, covering a surface of about 30,000 m², was located on a hill in a rural-natural area in the central part of Italy (Città Sant'Angelo, province of Pescara).
The plant area included 11 small buildings, used for storage or production, located on different land levels (due to the location on a hill). (Illustration1)

Illustration 1 : Layout of the plant

1. Unclassified products storage (products that do not fall under the Italian regulation on explosives storage and production)
2. Black powder storage (max 500 kg)
3. Fireworks laboratory
4. Products storage (max 4 t)
5. Products storage (max 9,6 t)
6. Mixing
7. Colours and various material storage
8. Products storage (max 9,6 t)
9. Engines installation
10. Coal crushing
11. Semi-finished products storage under authorization process (max 7 t). This building was not yet authorised at the moment of the accident.

Two residential buildings (the house of the facility's operator and the house of the facility's watchman) stood close to the plant, at the top of the hill, together with other small buildings used as trucks garages, offices or depots.

The plant produced and stored fireworks, following the process steps listed below:

- Raw material reception and storage;
- Semi finished products preparation;
- Inert crushing by millstone;
- Colorants mixing;
- Pressing;
- Finished products wrapping;
- Finished products storage.

The plant was classified as a "lower tier" establishment under the Seveso II Directive because of the presence of the following dangerous substances:

Substances	Max authorized quantity (t)	Seveso II tiers		Classification
		lower	upper	
Fireworks	23,2	10	50	R2-R3 ADR (1.1, 1.2, 1.3, 1.5, 1.6)
Black powder	0,5			ADR 1.1
Aluminium powder	1,5	5000	50000	F - R10
Titanium powder	0,3			F - R10
MgAl	0,7	5000	50000	F - R11
Magnesium	0,5	5000	50000	F - R11
Potassium/barium nitrate	2,5	50	200	O - R8
				O - R8
Potassium perchlorate	2			O - R9
Strontium nitrate	0,5			O - R8
Criolite	0,1	200	500	N - R51 /53

The involved equipments/units:

The accident involved a series of explosions. The first explosions occurred in the fireworks storage buildings Nr. 4 and 5 (Illustrations 1-2), which were completely destroyed.
Another explosion occurred, by domino effect, in building Nr. 8, also used as fireworks storage (Illustrations 1-2).
Seven of the eleven buildings of the plant were completely destroyed by the blast combined with the fire : buildings Nr. 2, 3, 4, 5, 6, 7, 8. Buildings 10 and 11 were partly damaged, while buildings 1 and 9 were strongly damaged.

Illustration 2 : The remains of the plant after the accident

Based on data provided by firefighters, it is supposed that a “pick-up truck” (a small truck with an open body and low sides), normally used for internal explosives transfer, has been involved in the first explosions. The remains of the pick-up were found near the storage buildings Nr. 4 and 5 (illustration 3).

Illustration 3 : The remains of the pick-up truck

THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

The accident:

On 25 July 2013, at 10:15 am, a sequence of explosions occurred in the storage area of fireworks plant.

At the moment of the accident, three workers (the operator himself and two technicians), were transferring fireworks from the buildings Nr. 4 and 5, used as fireworks storages, to a “pick-up” truck located in front of them. The pick-up was used for internal transfer. As a following step, the fireworks had to be loaded on some bigger trucks located in the area outside the entrance of the plant. These trucks were found partially loaded with explosives products after the accident.
The fireworks transfer operations were the trigger of the explosions.

Three explosions occurred in buildings Nr 4 and 5. The total amount of explosives stored inside these buildings exploded almost instantaneously, in a phenomenon called “mass explosion”.

After 40 minutes, a fourth explosion occurred in building Nr. 8, also used as explosives storage. This fourth explosion is probably due to a delayed domino effect. The building, already damaged by the blast wave of the first explosions, was probably hit by debris and flying sparks generated by minor blasts that occurred after the main explosions. Building Nr. 8 exploded in mass too.
On the whole, nearly the total amount of pyrotechnic substances stored in the plant was involved. Seven of the eleven buildings were completely destroyed : buildings Nr. 2, 3, 4, 5, 6, 7, 8. The other buildings were partly damaged (buildings 1, 9, 10 and 11).

Despite the scale of the accident, the company did not properly activate its internal emergency procedure.
Firefighters were called by the inhabitants of the near dwellings, who heard and saw the major effects of the explosions. Only after the firefighters had already received 8 calls by alarmed residents, did a call come from the company.

Moreover, after the first explosions, considering the dangerousness of the area (there were small blasts all over the plant), the workers were supposed to evacuate the area and to reach the safety meeting point located outside of the plant. But the evacuation signal was not given and the employees remained on the site. One worker, the operator’s son, even walked inside the damaged buildings to look for his missing father and got killed.

From 10:20 am to 7:30 pm, eight firefighters teams were involved to manage the emergency operations. Fire extinguishing was managed using numerous equipments such as fire-trucks, water pumps, helicopters, fire-planes.
Firefighters encountered difficulties in their intervention due to the layout of the access ways and of the plant itself. The space area outside the entrance of the plant was too small for an easy access of fire-trucks and equipments. There was only one access from where it was possible to manage the emergency. The set-up of the plant did not allow them to easily move their fire trucks and to manage the fire systems.

The emergency was considered concluded after 9 hours, during which other local Authorities arrived together with the prosecuting Authority, who seized the whole area.

The consequences of the accident:

Human consequences (inside the establishment)

The three persons that were occupied with the transfer operations, two technicians and the facility's operator, were instantly killed by the first series of explosions.
A 4th person, the operator's son, was hit by a piece of the roof projected by the explosion of building Nr. 8, while he was running nearby, looking for his missing father.
A fire fighter was also hit by a projection triggered by the explosion of building Nr 8. and died 3 months later in the hospital.
Besides, 3 workers and 5 fire fighters were also injured during emergency operations and hospitalised.

Material consequences

Inside the plant : The explosions caused the total destruction of almost all buildings of the establishment.

Outside the plant : The blast waves caused damages to several civil buildings (houses, church, factories,…) within a 500 m radius. Debris were projected within a radius of 1 km. In particular, a big piece of reinforced concrete (30 cm x 30 cm x 20 cm) was found 930 m away from the plant. (illustrations 4, 5).

Illustration 4 : Piece of concrete found more than 900 m away from the plant

Illustration 5 : Debris projected by the explosions

According to a preliminary evaluation, the accident caused a financial loss of about 1.5 millions euros:

- 600.000 euros for structural internal losses (equipments and structures destructions) and production loss;
- 900.000 euros for structural external damages.

Environmental consequences

The accident generated a sequence of fires in the rural/natural area surrounding the plant (in a 500 m radius). These fires were controlled and extinguished by the fire fighters. (illustration 6).

Illustration 6 : Fires in the area around the plant

Besides, around 8 tonnes of chemical products (flammable and oxidizing substances) used to prepare the fireworks were found spread on the ground outside the plant after the explosions.
Moreover, a big cloud of gaseous products (including toxic substances) was observed after the explosions (illustration 7).

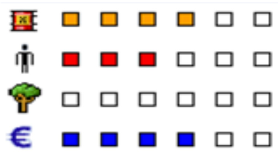
Illustration 7 : Toxic cloud emitted to the atmosphere

Considering the amounts of substances involved, and the fact that human, material and environmental consequences exceeded the thresholds indicated in Annex VI of the Seveso II Directive, the accident was classified as a “major accident”.

The European scale of industrial accidents

By applying the rating rules applicable to the 18 parameters of the scale officially adopted in February 1994 by the Member States' Competent Authority Committee for implementing the ‘SEVESO’ Directive on handling hazardous substances and in light of available information, this accident can be characterised by the four following indexes:

Dangerous materials released
Human and social consequences
Environmental consequences
Economic consequences



The index corresponds to hazardous substances released. Level "4" was reached since the accident involved pyrotechnic substances (quantity of explosive substances contributing to the explosion between 5 and 50 tonne of TNT equivalent).

The index corresponds to human and social consequences; it was scored a "3" due to the fact the accident caused 5 deaths and 8 injured persons).

The index corresponds to environmental consequences. No figures are available regarding the surface area of soil contaminated. Therefore, the index remains at level zero. However, environmental consequences of the accident should not be neglected.

The € index corresponds to economic consequences; it was scored a "4" due to the fact the accident caused between 0,5 and 2 million € of external losses).

The parameters composing these indexes and their rating methodology are available on the Web page: http://www.aria.developpement-durable.gouv.fr

THE ORIGIN, CAUSES AND CIRCUMSTANCES SURROUNDING THE ACCIDENT

The accident is still under investigation by the local prosecuting Authority. The area is still under seizure.
The elements contained in this section are therefore based on information and data provided so far by local firefighters and the State Police.
The MARS Commission (Major Accident Reporting System managed by the Major Accident Hazards Bureau from the European Commission), which also conducted an investigation, also obtained some information about the dynamics of the accident from the Company’s technical investigator.

On the basis of gathered elements, it is to identify some probable causes of the accident.

Presence of non-authorised products

After the accident, explosive products that the plant operator was not allowed to store were found in the remains of the plant._Indeed, fireworks already “armed” with an ignition device were discovered. (illustration 8). Other pre-armed fireworks were found inside the trucks parked just outside the plant, near the operator’s house.

Illustration 8 : Pre-armed fireworks

According to Italian regulation, fireworks should always be armed at the last moment, directly at the location of the pyrotechnical performance, and never in the production or storage facility. This measure is imposed because of the dangerousness of assembled fireworks. Operations such as transferring and loading of such pre-armed products are extremely risky. In that sense, there is not doubt that the transfer operations conducted by the workers in front of buildings Nr 4 and 5 were the trigger of the explosions.

The material damages observed in the storage buildings and their protection walls (illustrations 9, 10) show a real disintegration effect. This is the evidence of a "mass explosion" (the entire explosive amount exploded almost instantaneously). This phenomenon is a further proof of the presence of dangerous pre-assembled explosive products at the time of the accident.

Illustrations 9 and 10 : Damages caused to the buildings and their protection walls

Storage of excessive quantities

After the accident, local firefighters carried out an estimation of the effects of an explosion by applying the TNT equivalent method. They considered the maximum amounts of explosives that could have been stored within the buildings according to the authorisations. The results were that the real accident effects (effects' distances in a range from 100 to 500 m from the plant) were greater that the estimated effects (that remained within a radius of 100 m from the plant).

Moreover, a domino effect occurred in building Nr.8 40 minutes after the first explosions. As shown on illustration 11, building Nr. 8 had already been damaged by the first blast wave. The respect of safety distances among the buildings, according the national regulation, should allow to avoid domino effects. But these safety distances are of course a valid protection method only if the maximum quantities and the authorised typologies of explosives products have been respected (the safety distances are designed based on these parameters). The occurrence of a domino effect leads to conclude that there might have been violations of the regulation in terms of qualities and quantities of explosives stored in the plant.

Illustration 11 : view of the plant after the first series of explosions

Besides, 20 days after the accident, a non authorized amount of black powder (0,2 t) was discovered in a small disused building located outside the establishment, next to the south part of the fence. This quantity of 0,2 t, added to the 0,43 t regularly stored in building Nr. 2, exceeds the authorized limit (0,5 t) for black powder storage.

Productive pressure led to risk taking by the technicians

At the period of the year where the accident took place, summer time, the company was particularly busy in preparing fireworks that would be used to perform pyrotechnic shows in the nearby town festivals. Theses circumstances induced time pressure on the technicians, who were in a rush to perform their tasks. Indeed, as of 25 July 2013, there was only little time left before the next fireworks performance.
These time constraints, associated with a possible excess of confidence of the technicians regarding their level of management of their tasks (the three workers all had long time experience in managing explosives), could have led them to work in unsafe operative conditions. Productive pressure is probably what led the operator to overpass authorised quantities and to arm fireworks with detonators within the plant.

Defaults in plant design and emergency procedures led to increased consequences

Important defaults have been observed in the implementation of the internal emergency procedure during the events. The company failed to call the firefighters and failed to activate the evacuation plan after the first explosions. Considering the dangerousness of the situation after these first explosions, with debris scattered all over the area, evacuation should have been the first priority.
In addition, inadequate layout of the plant in terms of emergency access made difficult the access to the damaged area by the firefighters. Their management of fire engines and fire systems was made very challenging.

Besides, the inadequate location and layout of the watchman's and operator's family houses should be noted (visible on fig 2 and 11). The number and the separation distance between these civil buildings and the plant seemed inappropriate, considering the material damage that they suffered, both on the outside and on the inside.

Last but not least, there seemed to have been made use of inadequate material for the roof of the depots. Indeed, the debris coming from the roof because of the explosion of building Nr. 8 caused the death of a technician.

All these problems in terms of conception, design and procedures indicate that the plant operator did not properly take into account the regulatory requirements. They also reveal a lacking risks identification.

Warning signals insufficiently taken into account by the administrative control authority

About seven months before the accident, a detailed Safety Management System (SMS) inspection had been conducted by the Regional Environmental Agency. This inspection pointed out several serious defaults in the plant's SMS:

- Need to provide training to technicians and to respect its planning according to the specific requirements of the national law ;

- Need to provide detailed operational procedures explaining the safe way of managing fireworks storage and production ;
- Need to improve the emergency procedure including : description of emergency systems, description of communication methods between buildings, identification of emergency situations requiring evacuation, integration of the meeting point in the emergency map... ;
- Need to involve the personnel in the risk analysis and identification of possible near misses ;
- Need to guarantee a safe, clean and orderly arrangement of the explosives packages.

Some of the issues raised by this inspection can clearly be related to the causes of the accident from July 2013.
The question of the effectiveness of the inspection activities therefore arises. An effective inspection strategy should include a follow-up of the actions taken by an operator to correct the errors and defaults identified during a previous review.
If the operator had been forced to implement corrective measures after the defaults raised by the inspection, the accident might not have taken place or might not have had such heavy consequences.
From this point of view, the implementation of article 20.7 of Directive Seveso 2012/18 UE could help Member States to enhance the safety of the inspected establishments. This article states that :

> *"7. Within four months after each inspection, the competent authority shall communicate the conclusions of the inspection and all the necessary actions identified to the operator. The competent authority shall ensure that the operator takes all those necessary actions within a reasonable period after receipt of the communication."*

ACTIONS TAKEN

In the 10 days following the accident, heavy recovery operations were conducted by the local expert authorities, in order to remove and neutralize the residual explosive material, to remove the remains of the victims, and to secure the whole area. Static checks of the buildings in the area were also carried out.
No information about the action taken by the Company were collected, due to the destruction of the whole establishment and the death of the workers involved in the transfer operations.

The area involved was seized and a detailed investigation was carried out by the prosecuting Authority, supported by the local Authorities and technical experts.

LESSONS LEARNT

This accident, and the Safety Management System failures involved in the facts, draw the attention to some potential "vigilance points". These points are critical issues on which attention should be focused in fireworks plants:

- respect of safety regulation and safety procedures, in terms of quality (compatibility) and quantity of explosive products managed or stored inside a plant;
- safe operative conditions and adequate behaviour/competence of operators in working and preparing explosive products, especially during peaks of activity;
- adequate internal emergency procedure, especially in terms of activation of the emergency (call to the firefighters), and personnel evacuation;
- adequate layout of the plant, in terms of emergency access for external firefighters, in order to allow easy access to the area for fire trucks and other engines;
- respect of sufficient security distances between civil buildings (for example watchman's house) and the plant;
- use of adequate construction materials (for example for the roofs of the buildings), in order to avoid increased human consequences in case of an accident (example of dangerous debris coming from the roof after the explosion than caused serious damages to technicians and firefighters).

This accident although highlights the importance of a rigorous follow-up by the control authorities of the corrective actions taken to target the breakdowns or regulatory breaches put in evidence during inspections.

Source of photographs on this document: firefighters report (ARR).

Theme 4

Accidents with cross-border effects

Accidents with cross-border effects

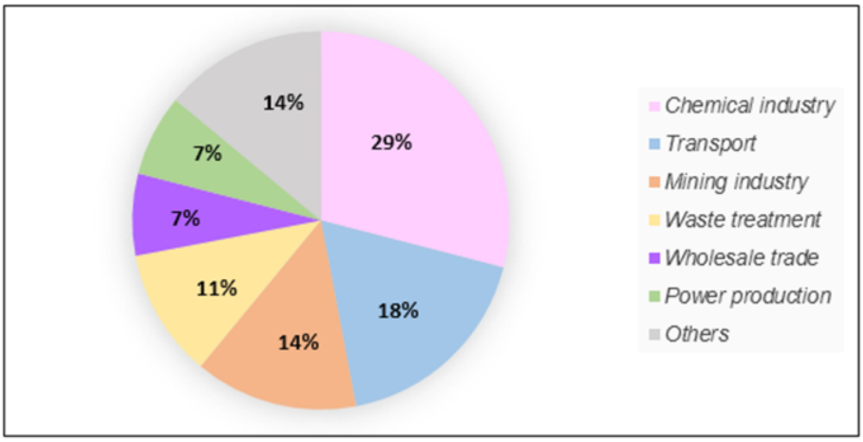
Accidental events whose consequences extend beyond national borders are, by definition, of significant magnitude and constitute for the most part major accidents. Of the 28 events categorised as such in the ARIA database, 23 occurred within the current European Union boundaries.

The Chernobyl disaster, which took place on 26 April 1986, is beyond a doubt the accident that made Europeans fully realise that borders could not protect against technological risks. While it is already difficult to standardise both the knowledge of risks and appropriate prevention practices across all facilities of a given country, achieving these goals at the international level remains an even more challenging task. Yet an analysis of accident studies in this field does prove to be vital.

1. Accident characteristics

1.1. Industrial activities involved

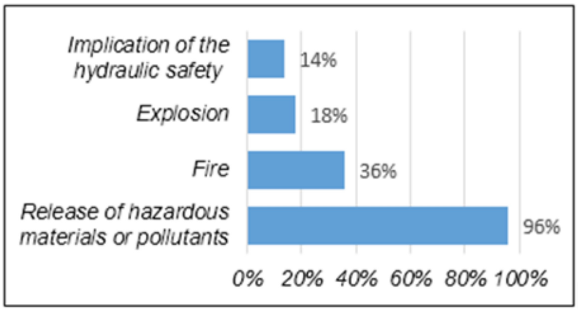
Among the activities involved in accidents with cross-border effects, we find the sectors generating the most widespread consequences. The percentage breakdown by type of activity of these 28 accidents is shown in the following graph.



Sectors of activities involved

1.2 Typology of cross-border accidents

While certain hazardous phenomena, such as explosions, fires or compromised hydraulic safety, are the cause of a number of accidents, it is still the discharge of hazardous substances which typically constitutes the cross-border characteristic of such events. This finding is depicted in the graph below, with percentages indicating the number of accidents in which the given phenomenon is present.



Hazardous phenomena present during accidents

1.3 Accident consequences

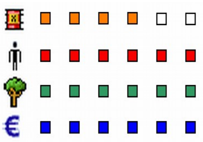
The consequences of these events are highly variable, to a point where providing an average is not representative. The number of accidents by type of consequence is listed in the following table:

Consequences	*Number of accidents*	*% of total*
Loss of life	*4*	*14%*
Serious / minor injuries	*2 / 7*	*7% / 25%*
Redundancy at work	*5*	*18%*
Loss of public services: drinking water or electricity	*8*	*29%*
Population evacuated / safety perimeter	*6 / 10*	*21% / 36%*
Environmental consequences	*27*	*96%*

Besides the lessons learnt from accidents presented in the next section for purposes of illustration, the most significant consequences of accidents with cross-border effects would include:

- ARIA 31005: 13 Nov 2005 in Jilin (China), a series of explosions in a petrochemical plant killed 5 and injured nearly 70 people. 10,000 residents were evacuated. 10 days later, the discharge of 100 tonnes of benzene was announced. Pollution of the river extended into Russia.
- ARIA 31312: 11 Dec 2005 in Buncefield (UK), explosions and a fire occurred in an oil depot, injuring 43 people. 20 tanks of hydrocarbons burned. A tremendous cloud of irritating substances spread all the way to southern England, then on to France and Spain.
- ARIA 32676: 18 Jan 2007 in Lyme Bay (UK), an English container ship ran aground. 200 containers, some of which were discharging hazardous substances and heavy fuel oil spilled. Kilometres of coastline on both the English and Brittany shores were polluted.

2. Accident examples



Pollution of the Rhine River by pesticides

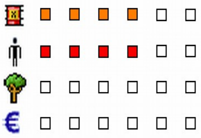
ARIA 5187 - 1 November 1986 - Schweizerhalle - Switzerland

Fire broke out in a warehouse containing phytosanitary products south of Basel. 80-m high flames were visible 10 km away. Mercaptans in the smoke made the air unbreathable for kilometres around, and the RHINE River was polluted. The retention basin was insufficient: 15,000 m³ of extinction water flowed via the sewer network into the river, which turned a shade of pink (fuchsine); **30 tonnes of highly toxic products (e.g. insecticides, mercury) destroyed all aquatic life over a stretch of more than 250 km.**

The time interval between the fire outbreak and the alert sent to residents of Basel and neighbouring countries caused a major public outcry. The investigation assigned the origin of the fire to an accidental ignition of a pallet of Prussian Blue.

Drinking water catchments were closed for 6 months and all fishing prohibited. Fire damage amounted to €34 million, while liability pay-outs totalled €24 million and site decontamination another €38 million. One year later, the International Commission for the Protection of the RHINE adopted an ambitious plan to restore river quality. The cost of environmental clean-up, decontamination and rehabilitation measures exceeded €40 million.

On 12 November 1986, the Environment Ministries of the adjacent countries met in Zurich to convince the Swiss to pass legislation similar to the **SEVESO Directive** and moreover to finance the river restoration initiative. **The Swiss wound up adopting legislation nearly matching** the SEVESO Directive, thereby raising the level of safety at industrial sites and improving information exchange between adjacent countries in the event of accident. This environmental disaster also gave rise to the 3 January 1992 Water Quality Law officially creating France's SDAGE framework (master planning of water facilities and management).



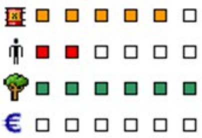
Explosion of a tank car containing toxic gas

ARIA 20821 - 14 July 2001 - Riverview - United States

At 3:45 am inside a chemical plant, 2 employees were unloading a tanker car containing methyl mercaptan (MM) when a process pipe broke loose: approx. **70 tonnes of gaseous MM** were released into the atmosphere. Fire-fighters sprinkled the car where smoke was emanating. At 4:09 am, the toxic gas ignited, engulfing the car and producing a fireball 61 m high by 15 m wide. The car exploded (BLEVE-type explosion) emitting both MM and its decomposition products into the atmosphere. The unloading hose on a nearby car containing chlorine was destroyed: **12 tonnes of chlorine** out of the 81 contained in the car were released. The toxic cloud drifted towards the Canadian border marked by the river running alongside the site. At 12:47 pm, the leak was finally stopped.

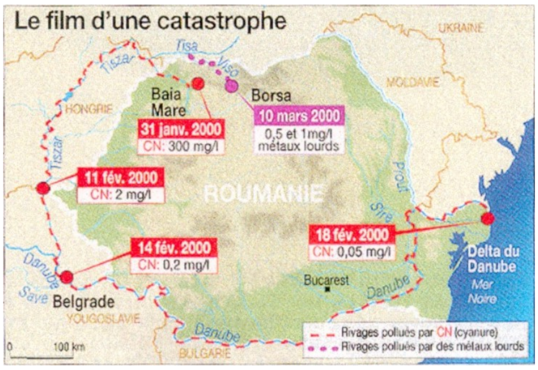
This accident **took the lives of 3 plant employees** and **injured 49**. Some 2,000 people had to be evacuated. The river was closed to all forms of navigation. The investigation concluded that a corrosion-erosion phenomenon had caused the pipe to break and singled out safety rule compliance breaches. The State of Michigan negotiated a $6.2 million settlement with the industrial group to compensate local residents, consisting of $500,000 in fines and $5.7 million to improve safety and training in addition to compensating the local population.

In March 2002, the chemical company announced a **general emergency programme** aimed at mitigating the consequences of explosions, fires and toxic discharges on public health and the environment. Periodic drills were scheduled with both American and Canadian fire-fighters. Updated evacuation procedures were ordered by the Head of Emergency Services. Canadian emergency planning authorities were not notified until several hours after the toxic cloud had crossed the border causing some Canadian residents to fall ill. Upon Canada's request, an **alert protocol specific to chemical leaks was adopted between authorities on both sides of the river**. This protocol involves authorities from 5 cities and 3 industries. A revision of Federal regulations was also initiated.



Water pollution due to cyanide effluent

ARIA 17265 - 30 January 2000 - Baia Mare - Romania



Inside a gold waste recycling facility opened in May 1999, a waste settling basin failed. **300,000 m³ of effluent containing cyanide** (400 mg/litre, for a total of 115 tonnes) **and heavy metals** (Cu, Zn) contaminated 14 hectares of ground and polluted the SASAR River. A 40-km long "cyanide wave" extended all the way to the DANUBE.

Romania, Hungary, Yugoslavia, Bulgaria and the Ukraine were all adversely affected. Strong cyanide concentrations were measured in wells on individual properties. Several people were exposed to toxic doses. All water consumption and fishing activities were prohibited. **Flora and fauna were destroyed for hundreds of kilometres around.**

A delegation of European experts analysed the event. The samples taken confirmed the persistence of this pollution. The origin of the accident was ascribed to dam design flaws, heavy rains and organisational deficiencies. It was nonetheless observed that an **alarm system** had successfully served to warn neighbouring countries. Information exchanges and measurements recorded by Romanian and Serbian authorities had undoubtedly **led to attenuating and mitigating the impacts** of this spill.

The seriousness and repetition of this type of accident led to strengthening European legislation, based on conclusions issued by experts and the Baia Mare working group, in particular through:

- the 16 Dec 2003, modification of the SEVESO 2 Directive to include the processing of ores as well as mining waste settling basins. Facility operators were required to implement safety management systems comprising risk assessments;

- the 15 March 2006 Directive relative to managing extractive industry waste in order to prevent or minimise the impacts of accidents and moreover to impose specific measures on installations capable of producing cross-border effects (e.g. informing all adjacent countries);

- within the framework of the IPPC (Integrated Pollution Prevention and Control) Directive, publication of a BREF (best available techniques reference) document as a means of reducing ordinary pollution while preventing accidents related to non-ferrous metal mining or at least mitigating their effects.

3. Lessons learnt

The accidents recorded in the ARIA database whose effects extend beyond national borders illustrate the need to address technological risks according to a global and standardised approach, as regards their prevention and specific risk management strategies. Several of the most significant events, in terms of impacting and mobilising public opinion, have given rise to regulatory modifications aimed at improving the knowledge of risks and minimising their effects, both during normal operations and in accident response. The aquatic environment is most often disturbed during events cited in the base.

For the 28 European Union member nations, the European Water Framework Directive, adopted on 23 October 2000 plays a strategic and fundamental role. It lays out guidelines for managing and protecting water on each major drainage basin across Europe, in addition to setting bold objectives for preserving and restoring the quality of surface water as well as groundwater, with the goal by 2015 of achieving a "good overall state" of water quality. Subsequent to this European initiative and in order to conduct coordinated action for the protection of border rivers and their primary tributaries, the pertinent countries founded a number of international committees, as exemplified by:

- CIPEL: International Commission for the Protection of Lake Geneva's waters, is a joint Franco-Swiss body assigned to monitor the evolution in water quality not only of the lake, but also of the Rhone River and its tributaries;
- CIPR: International Commission for the Protection of the Rhine. Nine nations have a stake in the sustainable development of this immense water basin: Switzerland, France, Germany, Luxembourg, the Netherlands, Austria, Lichtenstein, Belgium, and Italy.
- ICPDR: International Commission for the Protection of the Danube River. Founded in 1998, this body is composed of the European Union and 14 nations in the Danube region: Germany, Austria, the Czech Republic, Slovenia, Croatia, Bosnia and Herzegovina, Montenegro, Serbia, Slovakia, Hungary, the Ukraine, Romania, Bulgaria, and Moldavia.

Water management in France is organised according to the underlying principles of the European Water Directive via a series of master plans on water facilities and management (French acronym SDAGE) and 2010-2015 measurement programmes. The 2007 Grenelle Environment Roundtable committed France to achieving by 2015 "good overall water ecology", which is defined as water supply capable of sustaining a rich and varied animal and plant life, exempt of toxic products and available in sufficient quantity to satisfy all uses.

For more information :

* on water management in France and nation’s commitments to international programmes: www.eaufrance.fr

* detailed report on accidents with cross-border effects : ARIA 5187, 31312, 39047, 17265, 20821, 43616.

ECE Convention on the Transboundary Effects of Industrial Accidents (Industrial Accidents Convention)

1. The United Nations Economic Commission for Europe and its Environment Division

The United Nations Economic Commission for Europe (ECE) was created in 1947 as one of five regional commissions of the United Nations.
The others are the:

- Economic Commission for Africa (ECA) ;
- Economic and Social Commission for Asia and the Pacific (ESCAP) ;
- Economic Commission for Latin America and the Caribbean (ECLAC) ;
- Economic and Social Commission for Western Asia (ESCWA).

ECE has 56 countries located in the European Union, non-EU Western and Eastern Europe, South-Eastern Europe, the Commonwealth of Independent States (CIS) and North America. All these countries dialogue and cooperate under the aegis of UNECE on economic, environmental and other sectoral issues.

The Environment Division is one of the six Divisions of ECE. It hosts five environmental conventions, also known as multilateral environmental agreements or MEAs, all of which are now in force:

- Convention on Long-Range Transboundary Air Pollution;
- Convention on Environmental Impact Assessment in a Transboundary Context;
- Convention on the Protection and Use of Transboundary Watercourses and International Lakes;
- Convention on the Transboundary Effects of Industrial Accidents;
- Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters.

Some of the Conventions have one or more protocols into force.

While many of the UNECE environmental conventions started as regional instruments, a number of them have become or are in the process of going global, and the work under these MEAs has for a long time included States outside the UNECE region in their activities.

2. The Convention on the Transboundary Effects of Industrial Accidents

The Convention on the Transboundary Effects of Industrial Accidents (Industrial Accidents Convention, or the Convention) is one of the five MEAs hosted by ECE. Its first version was signed on 18 March 1992 in Helsinki by 27 Parties. At the beginning of 2015, it counted 41 Parties among ECE Member States. It provides a legal framework towards coordination and cooperation to prevent, be prepared for and respond to industrial accidents, especially those with transboundary consequences.
These accidents can be of technological nature, and they can also be caused by natural disasters (NATECH).

2.1. History

An accident at Sandoz agrochemical storehouse in Schweizerhalle, Basel, Switzerland on 1 November 1986 caused one of the most severe man-made environmental disasters in the history of Europe. This accident resulted in large volumes of firefighting water that drained into the Rhine River along with tons of pollutants. This created a long toxic plume flowing through Switzerland, France, Germany and the Netherlands. It significantly destroyed the biological life of the Rhine and killed hundreds of thousands fish.

Since the accident, the international community, especially in Europe, took many steps to improve the safety at industrial facilities and to protect international rivers and lakes. In particular, the UNECE Conventions on the Transboundary Effects of Industrial Accidents was being negotiated and eventually, adopted in 1992. The Convention entered into force in 2000.

Also policy development had been carried out at the level of the European Union. The so-called “Seveso legislation” goes hand in hand with the Convention. The Seveso directives are the means through which the EU, Party to the Convention, implements the requirements of the Convention.

2.2. The Convention and the EU Seveso legislation

The requirements of the Convention and of the Seveso legislation are fully compatible. The Convention has an annex (annex I) with substances within the scope of the Convention which Parties are required to identify and subsequently, notify to potentially affected Parties. This annex has been harmonised in 2014 with the Globally Harmonized System on the Classification of Chemicals (GHS) and, therefore, with the relevant annex of the Seveso III Directive.

Contrary to the Seveso legislation, the Convention does not have a two-tier approach. Only the installations falling under the Seveso upper-tier category fall under the Convention.

The main difference between the two frameworks is the transboundary aspect that characterises the Convention vis-à-vis other national legislation.

There are also several differences with regard to the terminology used, for instance the Convention speaks about “industrial accidents”, whereas the Seveso legislation talks about “major accidents”.

2.3. The Convention today

Under the Convention, Parties have to work nationally on:

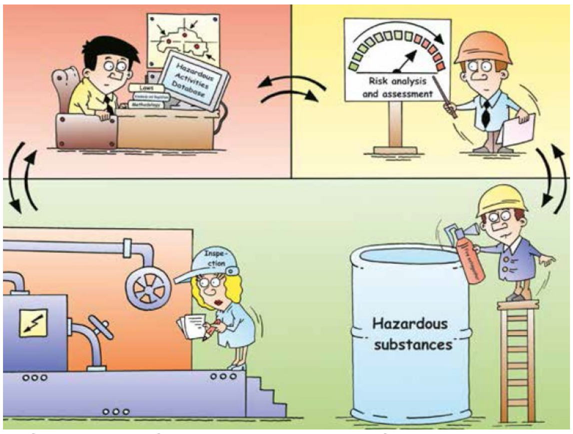
- Prevention (including ensuring that operators of installations reduce risks of accidents);
- Preparedness (including country development of institutions and mechanisms to ensure preparation, coordination, testing, review and revisions of emergency plans);
- Response (including building capacities to promptly recognise the magnitude of the accident, promptly coordinate the needed response measures and prompt use of early-warning systems);
- Public awareness and public participation in decision making (including involving the public in emergency exercises).

Parties also have duties internationally that include:

- Mutual assistance (including facilitating dialogue among countries and identifying actions to facilitate the assistance activities – border crossing for equipment and personnel during assistance etc.);
- Public awareness also in neighbouring countries;
- Exchange of technology and information.

3. Prevention

Industrial accidents can cause significant damage to communities and the environment, both locally and across borders. The first line of defence against industrial accidents is to prevent them from occurring. The Convention therefore requires Parties to place prevention at the heart of their efforts to minimize the effects of industrial accidents. Article 6 of the Convention obliges Parties to take preventive measures, further specified in Annex IV, including measures to be carried out by Parties, competent authorities, operators, or by joint efforts.



Source: UNECE Industrial Accidents Convention - ARR

A key step in preventing an industrial accident is to identify all hazardous activities within the jurisdiction of a Party. The Convention’s annex I (amended in 2006 and in 2014) provides criteria and lists for the identification of hazardous activities. Once a hazardous activity has been identified. According to articles 4 and 9 of the Convention, information on hazardous activities should be made available to the public and other countries that could be affected. Their cooperation will be required to reduce the transboundary impact of an industrial accident, should one occur.

As part of Parties' obligations with regard to prevention, article 6 also requires that the operators of any hazardous activity provide an analysis and evaluation of the activity to demonstrate its safe performance. Matters which should be considered in the analysis and evaluation are detailed in annex V.

The analysis of hazardous activities is especially important when new developments are being planned. Before any new industrial facility is constructed, proper land use planning should be conducted to determine the most suitable site. This should be done with the objective to minimize the risk to the population and the environment including in potentially affected Parties.

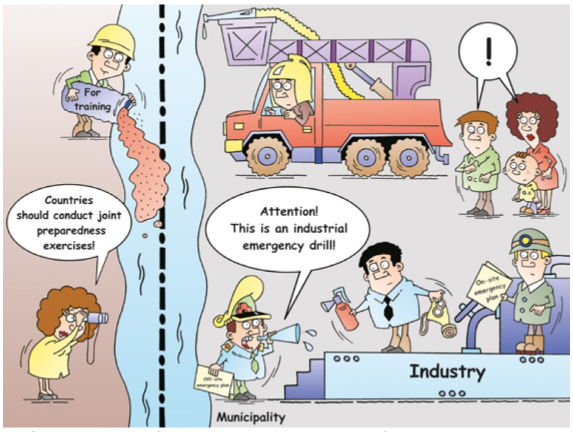
Prior to any industrial facility being built, meaningful and effective public participation should also take place. Annex VI of the Convention states that the results of public consultation and participation processes should be considered pursuant to Article 7, concerning decision-making on the location of hazardous activities. The Convention on Access to Information, Public Participation in Decision-making and Access to Justice (Aarhus Convention) also offers guidance in this regard.

To assist Parties in meeting their obligations with regard to the prevention of industrial accidents, several guidelines have been produced under the auspices of the Convention. These include Guidelines for Location Criteria, Safety Guidelines for Tailing Management Facilities, Safety Guidelines for Pipelines, and a Checklist System for Safety Reports.

4. Preparedness and Response

Despite best efforts, industrial accidents do sometimes occur. It is therefore very important that countries are fully prepared in order to reduce the impact of an industrial accident on communities and the environment.

In order to prepare for industrial accidents, countries should have identified hazardous facilities where an accident could occur as part of the prevention obligations of the Convention. All relevant authorities at the local, regional and national level should be fully prepared and have the proper equipment and training in place to deal with any accident scenario.



Source: UNECE Industrial Accidents Convention - ARR

Annex VII of the Convention specifies emergency preparedness measures pursuant to article 8, which requires the development of transboundary emergency plans. National emergency plans should be compatible with those of neighbouring countries, so that they are able to respond to transboundary impacts. Article 9 further determines that the public should have an opportunity to participate in the preparation of prevention and preparedness measures, as well as have access to judicial proceedings to appeal a relevant decision.

Responding promptly to an industrial accident is crucial in reducing its effects on communities and the environment. Emergency services personnel need to be mobilized and coordinated across local, regional and national authorities. In addition, procedures should be in place to inform the public in the event of an industrial accident or a threat thereof.

If an industrial accident has possible transboundary effects, Parties are required to inform neighbouring countries of the risks and share all available information necessary for an effective response. The Industrial Accident Notification (IAN) System has been created under the auspices of the Convention to facilitate the timely notification of countries that may be affected by an industrial accident.

The Convention encourages Parties to assist each other and cooperate in their response to industrial accidents, as well as in research and development and the sharing of information and technology. The Convention aims to provide a platform for cooperation within and between countries and the exchange of experience and good practices.

5. The Assistance Programme

In 2000, the Convention launched the Assistance Programme to support countries with economies in transition with the implementation of the Convention.

The Assistance Programme aims at supporting Parties and ECE countries with economies in transition to improve their industrial safety. The Programme is based on the principle that assistance can be effective only if a recipient country is capable of receiving the assistance and is willing to take advantage of it. The Strategic Approach, adopted in 2008, provides concrete tools for beneficiary countries of the Programme to self-assess their situation, monitor progress made, and request targeted assistance through an action plan and project proposal. For more information, please see the relevant documents and sections of the website at http://www.unece.org/env/teia/ap/introduction.html.

Source: UNECE Industrial Accidents Convention - ARR

Examples of activities carried out under the Programme include:

- Joint management of transboundary emergencies in the Danube River involving Serbia, Bulgaria and Romania (2009) ;
- A project about hazard and crisis management between Moldova, Romania and Ukraine (2011-2015) ;
- Joint inspections to hazardous industrial sites (2011 and 2012) ;
- Field exercise of response to accidental water pollution (planned for September 2015).

Products and communication materials on the Convention

The Convention is available at:
http://www.unece.org/fileadmin/DAM/env/documents/2013/TEIA/1321013_ENG_Web_New_ENG.pdf

The Convention has also been working on finding creative ways for promoting awareness among national institutions, industry, NGOs and the public about the importance of major accidents prevention, preparedness and response.

Examples of such efforts include:

* **Cartoons**, available at: http://www.unece.org/index.php?id=36970&L=0

* A short **film** about the Industrial Accidents Convention, available at:
https://www.youtube.com/watch?v=3Ph8jKOOaS0&index=1&list=PL4iZR0KyjSQ9VxjaqLHPk0yeXQYssy-Tz

* An **on-line training** on industrial accidents, available at: http://www.unece.org/index.php?id=32240&L=0

* **Publications** (for instance Sectoral Checklist for Preparation and Inspection of a Safety Report) available at: http://www.unece.org/environmental-policy/treaties/industrial-accidents/publications.html

Exercise : leak on a cross-border pipeline

The United Nations Economic Commission for Europe (ECE) Convention on the Transboundary Effects on Industrial Accidents (Industrial Accidents Convention) applies to the prevention of, the preparedness for and response to industrial accidents with possibility of causing transboundary effects. This includes the effects of such accidents caused by natural disasters.

In addition, the Convention has provisions concerning international cooperation on mutual assistance, research and development, exchange of information and exchange of technology. In this framework Parties are encouraged to create and maintain bi- and multi-lateral agreements between themselves and with neighbouring countries.

The following paragraphs will illustrate the provisions of the Convention concerning preparedness, response, cooperation and exchange of information. These paragraphs will serve as a background for the brief description of a transboundary response exercise organised by Belarus, Latvia and Lithuania in 2014.

1. The provisions of the Convention concerning preparedness, response cooperation and exchange of information

The Industrial Accidents Convention indicates in its article 8 the duties of Parties concerning emergency preparedness to industrial accidents, capable of having transboundary consequences. In particular it requires Parties to:

- Take measures to establish and maintain adequate emergency preparedness (on-site by the operator and off-site by the relevant authorities);
- Provide to the other Parties the elements that they would need to elaborate contingency plans;
- Endeavour to make the off-site contingency plans compatible (among neighbouring countries);
- Regularly review the contingency plans.

In annex VII, the Convention provides further information for the implementation of its article 8. In particular:

- It requires Parties to provide on-site personnel, people who might be affected, off-site and rescue forces with the details of technical and organisational procedures;
- It lists examples of matters to be covered by contingency plan:
  - Arrangements for warning people or, when appropriate, to evacuate them;
  - Organisational roles and responsibilities on-site for dealing with an emergency;
  - A description of the equipment and resources available;
  - Arrangements for providing early warning to the authority responsible for the off-site emergency response;
  - Arrangements for training personnel.
- It lists examples of matters to be covered by off-site emergency plans such as:
  - Organisational roles and responsibilities off-site;
  - Methods and procedures to be followed by emergency and medical personnel;
  - Methods for rapidly determining the affected area;
  - Identification of resources needed to implement the off-site contingency plan;
  - Arrangements for providing information to the public;
  - Arrangements for training and exercises.

Article 11 of the Convention requires that Parties, in the event of an industrial accident, take adequate response measures and ensure that the effects are assessed. More specifically, article 11 states that "Parties concerned shall ensure that the effects are assessed – where appropriate, jointly – for the purpose of taking adequate response measures. The Parties concerned shall endeavour to coordinate their response measures".


ARR

It also precises that effects of an accident can have impact on human beings, flora and fauna, soil, water, air and landscape and it recommends that effects on material assets and cultural heritage are assessed, after an accident.

The tasks and responsibilities outlined above, imply that parties must be able to conduct assessments of the effects of an industrial accident as a basis for taking adequate measures. Therefore Parties need to have a response policy and an organization for response. Such a policy will not be developed only for the response in the event of an industrial accident with transboundary consequences, but will be developed more generally for all kind of accidents and their effects on national, regional or local level.

At the same time, in its preamble, the Convention recognises “the importance and usefulness of bilateral and multilateral arrangements for the prevention of, preparedness for and response to the effects of industrial accidents”. The importance of bilateral or multilateral agreements and cooperation between Parties is furthermore reinforced through article 15 and annex XI, which include elements that can be subject of multilateral and bilateral cooperation:

- Measures and contingency plans at the appropriate level affecting other Parties;
- Measures taken regarding prevention of, preparedness for and response to industrial accidents;
- Emergency preparedness and response.

Finally, in article 24, entitled “Bilateral and Multilateral Agreements”, the Convention requires that Parties continue existing or enter into new bilateral or multilateral agreements or other arrangements. Furthermore, it states that the provisions of the Convention shall not affect the right of Parties to take, through bilateral or multilateral agreements, more stringent measures than those required by the Convention.

It is in the context outlined in the paragraphs above that Parties are encouraged to maintain and strengthen agreements and cooperation with neighbouring countries, especially with neighbouring Parties. In the framework of such agreements, meetings, training and exercises are organised not only involving authorities at central level, but also at regional and local level.

2. The exercise

The transboundary area between Belarus, Latvia and Lithuania is characterized by high concentration of chemical installations and dense transportation network which represents a potential threat of oil/chemical accidents in the region.

On 13 February 2014 at 10 a.m. a transboundary response exercise was started in Belarus. The scenario of the exercise had as a starting point an oil spill from a pipeline into the Dvina River and it involved in total 124 persons representing 27 units of three Parties to the Convention. The three Parties provided personnel and equipment to be used in the exercise.

The exercise was the concluding stage of a project involving Belarus, Latvia and Lithuania and concerning preparedness and response in a transboundary perspective. During the project, the three countries held several meetings, exchanged information about the respective legislation and organised training with the aim of strengthening response to industrial accidents with transboundary consequences.

The funding for the project was provided by the European Union, more specifically through the European Neighbourhood and Partnership Instrument 2007-2013 Cross Border Cooperation Programme Latvia-Lithuania-Belarus. This project, which was not the first one involving the three Parties, aimed at working together not only among the three countries’ authorities, but also with the operators, with the aim of minimising the effects of an oil spill in a river.

For this specific exercise it was decided that the scenario was to be based on an oil spill happening in winter. This was done on purpose to test the joint response capacities during the winter period, when rivers are covered with ice. Response capacities in summer had already been tested in previous exercises among the three countries.

Source : UNECE Industrial Accidents Convention - ARR

Source : UNECE Industrial Accidents Convention - ARR

The exercise had two main stages. One was in Belarus, where the oil spill originated. In this site, 65 people from Belarus actively participated to the exercise, including the operator.

The responders (and in this case the operator had the main role) had the task of containing the spill and collecting the oil in reservoirs set up for the purpose.

It was also decided to consider the possibility of a transboundary effect, should the measures undertaken in the first stage not be sufficient to contain the spill. The second stage was then set up in Latvia, where a joint unit of 59 people (20 from Latvia, 10 from Lithuania, 29 from Belarus) actively took part to the exercise. The aim was to contain the spill, de-contaminate the area and collect data. The joint unit was trained to respond to the accident.

The three countries decided that the scenario of the exercise and the exercise itself would test all the response chain. It also included aspects such as the installation of camps for the personnel and for the preparation of food. In the particular situation given by the winter scenario, extra equipment was needed for dealing with problems created by ice.

3. Lessons learnt

Transboundary response exercises, as transboundary response in real accidents, involve the cooperation of personnel from different countries, bringing with them their own equipment. Transporting equipment can be an issue for crossing the borders. In fact, customs regulations consider response equipment as goods crossing the border and therefore subject to its regulations. This aspect, especially when in a situation of emergency, can cause loss of precious time.

The three Parties taking part to the exercise decided, along with the development of the transboundary cooperation and further agreements, to develop a joint plan for emergency response that would also tackle the aspect of customs with the aim of accelerating the procedures and reduce the time needed for crossing the border.

The three Parties already made steps forward in their bilateral cooperation concerning visa issues for the response personnel crossing the border. Emergency visas can be obtained at the border for the emergency responders. This solution was achieved through bilateral agreements among the three Parties.

Source : UNECE Industrial Accidents Convention - ARR

Partner organizations for more information about the exercise:

- Latvia: State Fire and Rescue Service of Latvia (Riga);
- Lithuania: Utena Country Fire and Rescue Board (Utena);
- Belarus; Vitebsk Regional Department of the Ministry for Emergency Situations of Belarus (Vitebsk), State Fire Rescue Institution "Republican Special Response Team" of the Ministry for Emergency Situations of the Republic of Belarus (Minsk) and associates: Ministry for Emergency Situations of the Republic of Belarus (Minsk), State Institution "Republican Centre for Emergency Management and Response" of the Ministry for Emergency Situations of the Republic of Belarus (Minsk).

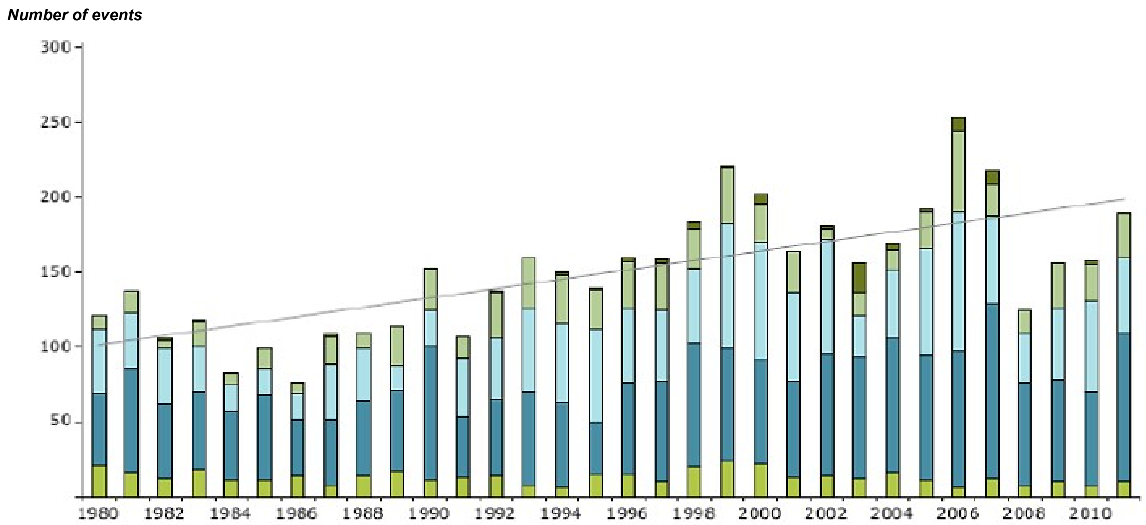
Theme 5

Technological incidents triggered by flooding

Technological incidents triggered by flooding

Many scientific studies undertaken by public or private-sector entities corroborate the observation of an increasing number of natural disasters over the past few decades. The rise in average temperature, as demonstrated by the Intergovernmental Panel of experts on Climate Change (IPCC), is modifying hydraulic systems at the global scale. This warming is also heightening the intensity of rainfall events, which are often very localised and contribute to extreme flooding. Flood events already make up the greatest share of Europe's most widespread natural disasters, accounting for 30% to 40% depending on the source. Anthropic factors, including land use, layout of water courses and the confinement of overflow zones, all heavily contribute to the occurrence of these sudden phenomena.

Graph No. 1: Natural disasters occurring in countries within the European Economic Area (1980-2011)



Geophysical events (earthquakes, tsunamis, volcanic eruptions) | **Meteorological events (storms)**

Hydrogeological events (floods, land movements) | **Climatic events (cold spells, droughts, forest fires)**

Climatic events (heat waves) | **Trend line (all events combined)**

Source: «Climate change, impacts and vulnerability in Europe 2012, An indicator-based report», rapport de l'Agence européenne pour l'environnement, n° 12/2012.

1. Typologies inventoried in the ARIA database

ARIA database entries on technological accidents clearly distinguish several types of floods that serve to trigger technological incidents:

- overflows,
- breaks along hydraulic structures (dykes or dams),
- slow spills (rising river water) or fast spills (torrential flows),
- a rising water table,
- agricultural or urban run-off,
- tidal surges.

On 31 December 2014, the ARIA database contained 244 accidents occurring subsequent to an external incident tied to overflowing water courses, tidal surges or other flood events.

The phenomena known to occur at the time of these technological accidents are as follows:

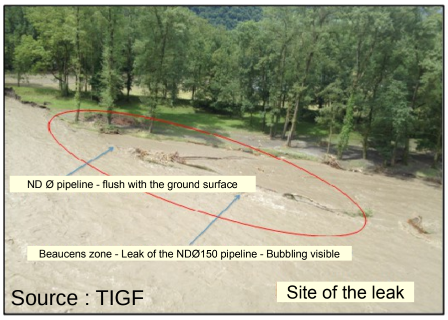
Known phenomena	*No. of accidents involved*	*Proportion (%)*
Discharges of hazardous substances	*53*	*21*
Fires	*9*	*4*
Explosions	*5*	*2*

Among the phenomena encountered most often during industrial accidents, the discharge of hazardous substances remains the most significant whenever industrial installations are flooded.
The rise in water level during natural events often:

- causes the failure of vessels containing hazardous substances;
- leads to overflowing liquid waste storage facilities, especially in aqueous effluent treatment plants;
- washes soils laden with all kinds of pollutants.

ARIA 44067 - CANATRANSGAZ - 19 June 2013 - 65 - PIERREFITTE-NESTALAS

When the GAVE DE PAU water course flooded at around 3 am, the operator of a gas pipeline (nominal diameter: 150; year of initial service start-up: 1962; underground depth: > 1 m), located roughly 100 metres from a water course, detected several anomalies (pressure variations) at the Pierrefitte-Nestalas station. Fire-fighters were notified at approx. 3:20 am. At 4 that morning, on-call technicians recorded a number of facility access difficulties: roads were cut, etc. Pressure continued to drop, and the leak flow rate was estimated at 9,000 Nm³/h at 8:30 am. A strong gas odour could be smelled in the vicinity. Implementation of the Monitoring and Response Plan commenced at 9 am.



A discharge point was identified around 10 am upstream of the Beaucens switching station. The current flowing in this water course had caused a total break of the pipeline and was responsible for destroying the bank where the line had run. The pipe had been unearthed, carried, bent and broken, all due to the strength of this current. Helicopter flyovers of the flood zones were performed from 10 am to noon in order to detect other high-risk situations between the towns of Tarbes and Lacq.
Once the waters had receded and after creating a secure zone (through excavation), works to isolate the leaking pipe section began around 7:30 pm and were completed by 1:30 am on 20 June. A curved bottom was installed over the decompressed section.
To ensure customers' gas needs were being met, notably for winter 2013-14, the distribution network grid was activated. Given the degraded operating conditions, the gas pipeline was rebuilt just a few hundred metres from the previous alignment. It was expected to be operational by the end of 2014.
The facility operator estimated the volume of natural gas released during the event at 233,000 Nm³ for the 17-hour leak duration.
The GAVE DE PAU flood was notable for the extent of its damage throughout the region, which was a function of not only the height of water generated but also the deviation in water course bed and hence in its preferential flow paths.

Other specific mechanical phenomena have resulted from floods. For example, Archimedes thrust is capable of lifting and dragging containers / vessels poorly fastened to the ground. Also, missile effects have been caused by the collision of floating objects during flood events.

2. Consequences

The majority of floods entering industrial facilities engender, first and foremost, property damage (motors and electrical grid, computer equipment, production tools, etc.), but also intangible losses (e.g. Data banks, customised software, computerised archives).

A breakdown of the primary consequences from the ARIA sampled events is shown below:

Consequences	*Number of accidents involved*	*Proportion (%)*
Operating losses	*133*	*55*
Redundancy of personnel	*58*	*24*
Surface water pollution	*41*	*17*
Soil pollution	*11*	*5*

In over half the cases, installation shutdown is required. Service restart is only partial at first and then staggered over several days or even a few weeks.

Emergency plan = Mitigated consequences

A study of 118 flood-related losses by the insurer FM GLOBAL, published in issue no. 457 of the specialised review *FACE AU RISQUE*, revealed the benefits of instituting emergency plans.
Out of the 72 cases where an emergency plan had been implemented efficiently, the average damage amount stood at €1.2 million.
In the other 46 cases, the average cost rose to €4.6 million. Moreover, an effective application of emergency plans enables restarting production activities much more quickly.

3. Disturbances and causes

Floods should be considered as intense natural events that contribute to triggering technological incidents. Nonetheless, this disruptive element does not, in the majority of cases, constitute the sole origin of accidents. More specifically, the failure to incorporate flood risks often proves to be a very strong indicator of organisational shortcomings.

From the time of site design:
- inadequate attention to risk analysis;
- insufficient sizing of distribution systems and evacuation facilities for tidal surges;
- failure to install and monitor protective structures.

While operating installations:
- lack of weather tracking;
- inconsistent management of hazardous substance stockpiles;
- no preliminary inspections of emergency response resources;
- poorly trained technicians.

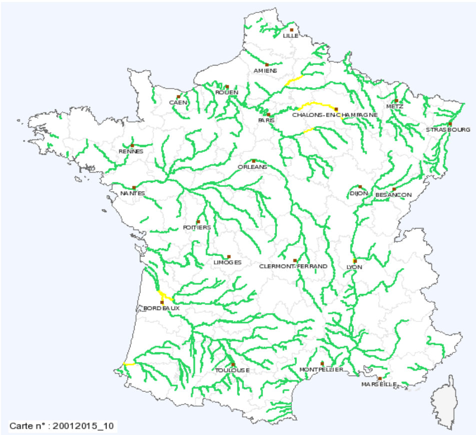
4. Measures adopted

According to the ARIA sample, the first measures enacted following flood events are technical in nature:
- electrical equipment moved to higher ground;
- the piping network assembled onto racks;
- transfer of external storage or fencing to avoid being swept away by floodwaters;
- construction of protective dykes.

These technical measures are accompanied by organisational actions:
- revision of the installation safety report to account for the flood risk;
- drafting and dissemination of guidelines for securing installations ahead of time;
- adoption of an emergency evacuation plan for personnel.

5. LESSONS LEARNT

Despite the speed and intensity of flood events, regardless of origin, their anticipation appears to be of utmost importance. Along these lines, a number of best practices are worth recalling:
- remain vigilant of weather conditions by using an alert system as required,
- on a regular basis, inspect all existing protective structures,
- place all computer servers and hardware on an upper floor,
- isolate all sensitive documents (drawings, patents, essential archives, etc.) in sealed containers,
- turn off energy supplies (gas, electricity) before the water level begins to rise,
- raise all important electrical devices off the ground.



Flood alert system:
Ministry of Ecology: http://www.vigicrues.gouv.fr/
Météo France weather service: http://france.meteofrance.com/vigilance/Accueil
"Predict" system (a *Météo France* subsidiary): http://www.predictservices.com/

Red : Major flood risk. Direct and widespread threat to personal safety and property security

Orange: Risk of a flood event generating heavy overflows capable of causing a significant impact on local communities and on personal safety and property security

Yellow: Risk of flooding or a rapid rise in water level without the threat of extensive property damage, yet still requiring extra vigilance in the case of seasonal and/or vulnerable activities.

Green: No extra vigilance required.

Conclusion

The extent of physical consequences caused by floods can lead to definitively halting certain activities or even an entire industrial site. As such, incorporating this risk as of the design stage, but also at the time of each modification, serves to significantly reduce financial losses, which when uncontrolled could ruin a company. Prevention must therefore be practised:

- It seems essential from the outset to identify and then analyse this flood risk;
- The second step consists to get prepared to face this risk, with priority on avoiding any construction in flood zones, insofar as possible;
- Next, protective measures must be implemented. Technical actions, like dyke building, at the site or industrial zone scale must undergo periodic verifications;
- Lastly, an emergency plan needs to be developed in order to: organise alert procedures, notify response teams, quickly provide all useful instructions and equipment, and easily identify the individual or individuals empowered to make operational decisions.

The General Directorate for Risk Prevention (DGPR) with the Ministry of Sustainable Development has earned recognition at the international level for its competence in handling flood risks. Increasing flood intensity and frequency, as well as its potential impact on industrial sites, led DGPR to create a new working group whose primary objectives include producing a guidebook. Such a resource is intended to enable operators to devise a strategy for acknowledging flood impacts with the aim of minimising their ultimate effects. This group's members include industrial risk specialists: professional organisations, insurance representatives, experts, and DGPR staff.

For more information:

Consult our website http://www.aria.developpement-durable.gouv.fr/ for many *NaTech* accident analyses.

Heavy rains and flooding:

- Summary: "Atmospheric precipitation and floods: Key elements from industrial accident studies",
- Press article: "Industry and flooding: Input for experience feedback",
- Detailed fact sheet: "The impact of floods on Seveso-rated facilities: A series of events from 1993 to 2003 in both the PACA and Languedoc-Roussillon Regions (France)".

Flooding strikes a solvent recycling factory

7 May 2014

Buchères (Aube)

France

Natural hazards
Rising waters
Flood
Response / Emergency
Safety (safe operating mode)
Water damage

THE FACILITIES INVOLVED

The site:

Chemical plant specialised in producing alcohol and recycling solvents, located in Buchères (Aube-10)

Installed approximately 500 metres from the SEINE River in Buchères within the Aude Department, 5 km southeast of the city of Troyes, the company was affiliated with a French sugar manufacturing group possessing several plants across France. The Buchères site was specialised in: producing agricultural alcohol, regenerating alcohols and solvents, distilling vineyard co-products, and drying sewage sludge.

The company had been authorised to store over 22,000 tonnes of flammable liquids, 9,000 tonnes of untreated wastes (including 500 tonnes of methanol), and 13,500 tonnes of treated wastes, in addition to producing 95,000 tonnes/year of regenerated solvents. For this reason, the site, located in a zone primarily dedicated to industrial activities, was ascribed an upper-tier SEVESO classification.

The distillery, which relied on sugar beets, began operations in 1946. An alcohol regeneration activity was set up in 1996 that included workshops for regenerating residual alcohol originating from the perfume industry, pharmaceutical applications and fine chemicals production, along with several dehydration stations. Following the company's 2000 buyout by a French sugar manufacturing group, its solvent regeneration capacity, which represents the site's most important current activity, was expanded. In 2012, the site invested in a 15 MW biomass boiler.

The manufacturing workshop (distillation units) and steam production installations run continuously throughout the year, with some 80 employees; the site's yearly output presently amounts to 400,000 hectolitres of agricultural alcohol and 45,000 tonnes of regenerated solvents, for an annual turnover of roughly €55 million.

Waste treatment and regeneration: Industrial ecology
The treatment of waste containing solvent is based on physico-chemical processes: distillation, settling, phase separation, filtration, absorption, desorption, redox reactions, neutralisation, pH adjustment, and precipitation.

The primary solvents treated are: ethanol, isopropanol, methanol, ketones, and chlorobenzene.

This activity requires a substantial industrial tool (distillation workshops, loading stations, storage zones, boiler room, control room, analytical laboratory), along with a high-quality and robust organisation. Ultimately, the material reuse process offers these solvents a second life.

Waste treatment and regeneration (ARR operator)

THE FLOOD, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

The flood:


Rising SEINE water (ARR)

On 6 May 2013 at 11 am, the Aube Department Prefecture informed the factory operator that subsequent to a period of intense rainfall, the SEINE River was expected to overflow its banks around nightfall. A meeting of the crisis response unit was held at the Prefecture with mayors of the various municipalities concerned. The Prefect requested that each municipality activate its rescue plan, and the mayors decided to adopt all prevention measures necessary to save the population and local companies. At the end of 6 May, Departmental Fire and Emergency Services visited city districts showing the potential for flooding to notify residents.

The operator assembled a crisis unit as of 6 May and activated the facility's internal emergency plan. This state of crisis management would last until 15 May. The objectives assigned this unit were as follows:

- placing the installations in safe operating mode;
- informing all appropriate government agencies;
- notifying mayors and local homeowner associations;
- managing related activities (clients, suppliers, etc.);
- responding to the heavy media attention;
- preparing the logistics for a successful facility restart and resumption of production.


Chemical plant overwhelmed by water
(source: DREAL Champagne-Ardenne)

The operator placed the site in safe operating mode even though the magnitude of the flood that would strike could not be foreseen: utility lines (gas, electricity) turned off, shutdown of the wastewater treatment plant, computer equipment moved to higher ground, sensitive inventories and lorries awaiting delivery removed from the site, evacuation order for a stockpile of wood boards used to fuel the biomass boiler. The storage of hazardous substances (alcohols and solvents) was protected by existing retention walls. All staff were evacuated from the premises.

The rising water reached a peak danger level very quickly (50 cm higher in just a few hours), which required the emergency evacuation of personnel.

Given a location closer to the SEINE than the site itself, the treatment plant was the first facility struck: as of 2 pm, water penetrated inside the electric utility rooms at a height of over 10 cm. Both the plant's biological basins and settlement tanks had been installed on higher ground and remained intact. Water first entered the chemical complex around 4 pm. At 11:30 pm, the facility director decided to shut down the workshops (one by one) depending on the safety margin available relative to the water level. At 1 am, water reached the basin next to the site entrance and flooded this sector; it then surrounded the stockpile of wood boards, which could not be entirely removed for lack of time.

The next morning, on 7 May, the site was totally flooded, with the exception of the biomass storage zone and the barrelling workshop. Water level in the facility was varying between 10 cm and 1.50 m, depending on the specific spot.

The factory operator crisis response unit temporarily banned access to the site given the risk of sewer manhole covers popping up.

The Inspection Authorities for Classified Facilities was first notified at 7:30 am and provided regular updates throughout the event duration.

Organisation of the crisis response planned by the factory operator included an on-call team composed of some 10 staff members, featuring the heads of maintenance, Safety, Health and Environmental (HSE) affairs and production plus the Director. This set-up enabled assessing the efficiency of measures adopted from the time flood waters were announced to monitoring the rising water height and establishing the conditions for factory restart once the waters had subsided.

The Classified Facilities Inspector assigned to oversee the site visited the factory on 9 May and observed, two days after the waters first overflowed, that it was still impossible to access the flooded areas. This "partial" inspection (from outside the fence) also concluded that the most heavily flooded part (up to 1.5 m of water) extended from the cafeteria to the storage platform for harvested wood. This platform itself had sustained less damage, but its access path was completely submerged. Empty barrels had drifted out to the property boundary and ripped apart the fence. These barrels had been recovered by the operator one at a time. Note was made of the presence of a few half-submerged barrels of solvents that nonetheless had not been lifted by the flood water. The inspector returned for a visit on 12 May and recorded that the site was no longer flooded, with 70% of premises being completely dry thanks to the pumping efforts of rescue teams. The operator sought to partially resume site activities the next day, beginning with logistics units (unloading of awaiting tanker lorries) and then restarting the solvent regeneration activity once the treatment plant was operational.

Wood storage at the plant overwhelmed by water
(Source: DREAL Champagne-Ardenne)

Consequences of the accident:

This flooding event affected several companies (ARIA nos. 43787, 43789, 43791) within the Buchères industrial park, where this chemical complex was located, in addition to nearby dwellings. 30 homes were flooded to some extent. Torrents of water and sludge advanced at high flow rates. The geographic territories most adversely affected by this flood were designated natural disaster zones. Hydrocarbon pollution caused by transport firms was also reported. Fields and gardens were not spared. The Prefecture, assisted by a local farmer, decided to build a wall of sandbags to protect the Troyes municipal water pumping station and thereby avoid the entire metropolitan area losing its drinking water supply.

Loading platforms at the neighbouring firm (ARR)

As regards the chemical plant, when the water reached its high point on-site, the levels recorded ranged between 10 cm and 1 m on the premises, and up to 1.5 m on the parking lot.

No chronic or technological accident tied to this installation had occurred; property damage and production losses were estimated at a total of €2 million. No assessment of partial personnel redundancies was offered while the plant was idle.

The shutdown of utility lines served to eliminate all electrical and fire risks, as well as any gas-related hazard.

The large quantity of wood stored on the dedicated platform prevented the full removal of these contents despite the flood warning issued. The woodpile got slightly moved through flotation during the flood period (trunks and boards).

The site's internal roads along the water's path were washed away by the current.

Portions of the fence had to be replaced subsequent to damage by the drifting of empty barrels.

In the various workshops, approximately 150 flooded pump motors were disassembled and shipped to a subcontractor for drying, reconditioning and an ATEX certification (i.e. with no risk of explosion).

The safety data transmission network between storage zones and the control room was down (this network included fire detection, local tank level measurements, and a nitrogen inerting system) and required repairs.

Fire-fighting means remained partially operational: two electric generating sets, including their batteries, were flooded while two other diesel-powered sets stayed dry and thus operational.

Water present in the sludge drying greenhouses, which rose to a height of approx. 40 cm, was pumped and routed to the treatment plant as of 15 May, once the plant had come back online. The operator informed neighbours that the plant's aeration basin (non-submerged) would be reactivated, potentially causing foul odours.

Storage facilities dedicated to flammable liquids and liquid chemicals were protected by retention walls that served to prevent water from flowing towards the tanks (with these retention basins designed to mitigate the consequences of tank leaks). Nonetheless, the presence of water (approx. 15 to 30 cm) inside the oldest basins made it possible to establish that their seals had been breached.

The Prefecture and departmental fire services decided to dig a trench down the middle of the departmental highway leading to the Buchères train station for the purpose of inserting a culvert to drain water that had accumulated at the plant as well as at the neighbouring transport company. In response to the announcement of another flood event by week's end, the Prefect decided on Thursday, 15 May, to build a 400 m long, 3 m wide dyke to protect the district surrounding the train station and adjacent businesses. An earthworks firm was hired and, with the assistance of 20 railway ballast cars, the dyke could be erected in 3 days.

Depiction (in yellow) of the dyke built during this flood episode (ARR operator)

Site activity could partially resume on 13 May (acceptance of cisterns) after an extensive clean-up of flooded zones and the verification/drying of damaged equipment (pumps, motors and transformers). However, since the transmission of safety-related data between storage sites and the control room was not operational, the operator implemented a number of compensatory measures, including the permanent monitoring of tank transfers and manual tank gauging. Both the manufacturing workshops and treatment plant were placed back into service on 15 May.

European scale of industrial accidents:

By applying the rating rules applicable to the 18 parameters of the scale officially adopted in February 1994 by the Member States' Competent Authority Committee for implementing the 'SEVESO' Directive on handling hazardous substances and in light of information available, this accident can be characterised by the four following indices:

Dangerous waste released	□ □ □ □ □ □
Human and labour-related consequences	□ □ □ □ □ □
Environmental consequences	□ □ □ □ □ □
Economic consequences	■ ■ ■ □ □ □

The parameters composing these indices and their rating methodology are available at: www.aria.developpement-durable.gouv.fr.

THE ORIGIN, CAUSES AND CIRCUMSTANCES OF THE ACCIDENT

This flood event was caused by heavy rainfall during the previous days. The municipality of Buchères had approved a Flood Risk Prevention Plan in June 2001, given that proximity to the SEINE River in the event of high water levels could flood parcels situated on the Seine's banks. A portion of the chemical plant's site boundary was actually located on a designated non-developable zone according to this Prevention Plan.

According to the operator, the extension of a large flat silo upstream of the site may have triggered flooding at the plant by deviating the watercourse and hindering its natural flow. The most recent reference event, dating back to 1983, had not actually reached the site (beyond the treatment plant closer to the river), at a time the silo had not yet been expanded.

ACTIONS TAKEN

This upper-tier SEVESO-rated chemical complex had been specially monitored throughout the flood episode, notably with the close watch of Classified Facilities inspectors, who were in daily contact with the operator. Two inspections were conducted: in order to authorise the quick resumption of site activity under safe conditions, inspectors proposed measures to compensate for the absence of safety data transmission to the control room. To avoid the risk of overflow around flammable product storage tanks, the operator proceeded with a manual gauging of the tanks several times a day. This gradual restart first focused on three tanks out of the 20 located on-site. The flood served to indicate breaches in the seal on some of the retention facilities for flammable liquid tanks. The more recent retention structures had remained dry, whereas the older ones, exposed to the thrust of water, had flooded from their base (joint ruptures). Classified Facilities inspectors requested that upcoming verifications, in accordance with the approved industrial installation modernisation plan, include specific points on the condition of both basins and blocks, with a ranking of the observed disorders based on available professional guides and an indication of associated repair time constraints. The operator had initiated a comprehensive and detailed expert appraisal of all basins, including an inspection of seals and repair specifications as needed.

Retention basin for an unsealed tank
(Source: DREAL Champagne-Ardenne)

LESSONS LEARNT

- The entire set of actors involved were in agreement in highlighting the effective crisis management performed by the plant operator, including communication with State agencies, the media and site neighbours. The drill held within the scope of the External Emergency Plan a few months prior to this event had enabled a rehearsal of these automatic reflexes, thereby underscoring the importance of regularly organising Emergency Plan drills.
- The fact that the plant operator had been informed ahead of time to move the wood board stockpile, coupled with the permanent presence of a watchman, made it possible to significantly limit damage and hence costs. The prevention measures to be adopted once a flood warning has been issued are, in fact, essential (turning off utility lines, closing workshops, shutting down the treatment plant, removing or stowing all inventory capable

of being carried away by floodwaters, raising computer and safety equipment above the water level, securing the storage of flammable and chemical liquids, etc.). These measures could be detailed in the operator's response plan (e.g. a dedicated chapter of the Internal Emergency Plan).

- For this site, an agreement between the Territorial Directorate and the operator had been signed as part of the authorisation granted for the biomass storage platform located in a flood risk zone. This agreement stipulated notifying the operator immediately upon learning of a flood risk so as to evacuate the wood inventory within 48 hours. During this event, the operator had in fact been notified well in advance, which made it possible not only to evacuate a portion of the wood stockpile, but also to very quickly implement appropriate prevention measures and thus mitigate the impacts. More than an agreement to a protocol for notifying operators, regular consultation of the website on flood warnings has been included among the best practices to adopt.
- The retention basin seal defects, which could be identified indirectly through this flood episode, are listed as a verification step in the industrial installation modernisation plan. In 2010, the government enacted a control plan for risks related to ageing industrial installations, pipelines transporting hazardous substances and pressure equipment. This case helps reinforce the need to continue verification actions, by means of site inspections in facilities requiring such authorisations, aimed at compliance with regulatory indications for all equipment targeted by the classified facilities modernisation plan (Ministerial decrees issued on 3rd and 4th October, 2010).
- This event demonstrates that flood risks in an industrial zone must be managed comprehensively, including all relevant sites, in preventing protection measures specific to a given site from exacerbating risks for neighbouring sites.
- Within the scope of revising the Flood Risk Prevention Plan, the operator was working in concert with the Departmental Labour Office to determine the best solution guaranteeing the site's durability and growth. The zone dedicated to sludge drying, which is now being closed, actually offers extra land for the operator. It is important for the site's development that this zone be allowed to accommodate new activities. Along these lines, the operator has commissioned a study by a certified hydrogeological consultant to indicate the improvements to be implemented in order to confine another flood of this magnitude as much as possible within the river's main bed.

Flooding of Process Industry sites

05-06 December 2013

East coast

United Kingdom

Natural risks
Prevention mesures
Communication/crisis
Rupture/dike
Insulation
Reglementation/COMAH

EVENT DESCRIPTION

On 5 and 6 December 2013, a storm surge coincided with high spring tides to produce similar water levels to those seen in the catastrophic East Coast Floods of 1953. The surge affected the north-west, east and south coasts of England. The event was forecast early with guidance issued to Category 1 and Category 2 responders and warnings issued to the public. Advanced preparations and plans undertaken by the multi agency East Coast Planning Group were implemented. There were no fatalities due to flooding and 800,000 properties were protected by flood risk management assets. There were 71 Severe Flood Warnings issued and 2,800 properties flooded along the east coast.

Four Seveso and one IED regulated establishments were extremely badly effected by the event. A large number of other Industrial establishments were also affected indirectly, partly because they paused production during the event and more seriously because their logistics were badly affected as most of the establishments actually effected service production plant.

In summary the incident saw:

- Largest coastal flood incident in 60 years for east coast ;
- Highest water levels ever recorded at all English East Coast Gauges ;
- Maximum surge of 2.5m at Lowestoft and 1.03m at Sheerness on 5 December ;
- Thames Barrier saw highest tide since its completion in 1984 (Thames levels in 1953 were approx 0.6m higher) ;
- The Storm surge affected 3 successive tides.

The Environment Agency (EA) contacted all the registered major hazard sites regulated under the Seveso Directive (COMAH Regulations in the UK) which were potentially at risk of inundation to ensure they had received our flood warnings. They were advised to put Flood Plans in place. This involves actions such as, moving chemicals to higher ground, suspending production and isolating electrical equipment in areas at high risk of flooding.

There are 145 Seveso Directive establishments along the stretch of coast which was impacted by the East Coast surge in 1953. Due to enhanced protection and better incident preparation and planning only five of these were impacted by the December 2013 East Coast event. A cement works, which is an installation regulated under the Industrial Emission Directive (IED), was flooded. This site, and most of the Seveso sites impacted, are considered in more detail below.

IMPACTS ON SITES ON TEESSIDE

Inter Terminals, Riverside Terminal

Site description

Inter Terminals, Riverside Terminal, is located on the north bank of the River Tees. The site provides bulk liquid chemical storage in above ground storage tanks with facilities to carry out import/export operations associated with shipping, road vehicle and pipeline transfers. It is an upper tier Seveso storage operation. The site is substantially automated with remote valve operation to enable transfer routes to be selected automatically.

Source Environment Agency

Preparations for flooding

The Terminal is situated in a highly vulnerable flood location and a flood risk assessment had been carried out ; site plans with topographical information were available. Emergency response plans and evacuation plans were in place and some employees were registered with the EA flood warning system. The river defence protection level was 4.15m AOD (metres above ordnance datum), but lower areas existed along the Billingham Beck around the south side of the site.

During the run up to 5 December, several flood warnings were received with predicted increased water levels as a result of the potential storm surge. Terminal operations including shipping, road loading and pipeline transfers continued during the week. With the site being located several miles inland from the east coast, the impact of the potential surge was not fully recognised until 5 December when operations were shut down and electrical power isolated prior to the arrival of the storm surge.

The flooding on 5-6 December 2013

Figure 2 - View of terminal being flooded from ship moored up on jetty, source Cleveland EPU

The storm surge caused a rise in the tidal river level to rise to 4.3m AOD which over topped the flood defence and Billingham Beck. The overtopping caused erosion thus lowering the effective protection level. The huge volume of flood water entering the site from the embankment and the Beck resulted in the whole site being flooded to a depth of 1.8 m.

Site personnel sought safe refuge in the site control room on the upper floor of the main office building, adjacent to the embankment. Most of the bund walls were overtopped and several tanks with low inventory were floated from their bases, damaging pipework and supports. Mobile equipment floated and moved with the inrush of flood water to cause impact on other stationary infrastructure. There was no loss of containment of any product.

Short term site recovery

The low level of the site meant that the flood water was unable to flow back to the river. After receiving authorisation from the Environment Agency, flood water was pumped back into the river to allow access to key parts of the plant. In the short term mobile generators were provided for essential utility power. The terminal remained inoperable during this immediate recovery period.

Figure 3 : Breach in flood defence with temporary staunching, source Inter Terminals

Long term site recovery

The main electrical switchgear and process control systems were rendered inoperable and substantial work to replace the equipment was undertaken. Key systems such as level alarms and tank gauges were prioritised for immediate attention. Transfer operations which were previously automatic controlled were being managed manually and temporary operating procedures were rapidly put in place to cover this operation.

Primary containment systems were inspected from an asset integrity perspective and any remedial works identified which included the repositioning of storage tanks, pipeline replacement and repair, electrical equipment replacement and testing. A post flood review was undertaken which brainstormed events leading up to the and during the flood to identify learning points.

The river defence embankment is now being raised to 4.85m AOD and work to protect the rest of the site boundary to this same level is also planned. The final protection of the site will be 1 in 1000 (0.1 %) annual chance of flooding in any year.

SABIC UK Brinefields

Site description

SABIC UK Petrochemicals Limited is part of the SABIC Group, with the ultimate parent company being Saudi Basic Industries Corporation based in Riyadh, Saudi Arabia. Its main operation is to manufacture bulk petrochemical products (Ethylene, Propylene, Butadiene, Cyclohexane, and Benzene) at a number of plants on the Tees Estuary. This involves a high degree of integration with other operating sites on Teesside and the United Kingdom. Storage of products and intermediates in the Cavities on the brinefield is a vital element of this integration. The brinefiled has a multi-million pound turnover and is part of an upper tier Seveso site holding large inventories of hydrocarbons.

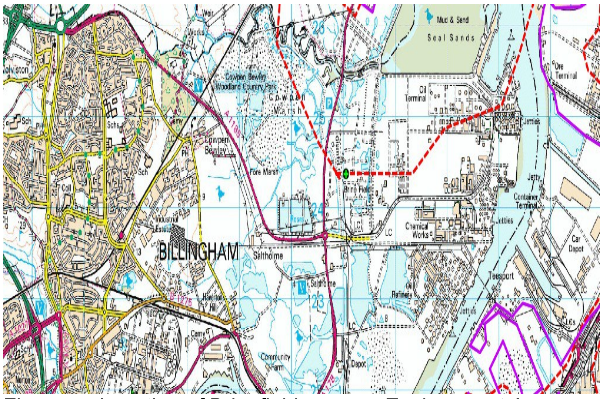


Figure 4 : Location of Brinefields source Environment Agency

Preparations for flooding

SABIC participated in the National Flood Preparation Exercise 'Watermark' in 2011 and the many valuable lessons learnt from that exercise were incorporated into the existing emergency response protocols. The protocols were further tested as part of the Serveso 'Live Play' exercises in subsequent years. When flood warnings were received during the first week of December, SABIC implemented standard operating practices to prepare for the tidal surge. These preparations included; emptying the effluent treatment facilities, isolation of all non-essential electrical equipment; sandbagging of vulnerable areas such as switch houses and removal of all containers that could float. As such when the high tide occurred on the late afternoon of 5 December 2013, the Site was prepared and monitored for a breach of the Tees estuary flood defences.

The flooding on 5-6 December 2013


Figure 5 : SABIC Brinefields and the flood defence breach, source Environment Agency

When the high tide occurred on the late afternoon of 5 December 2013, monitoring of river levels was focused on the banks of the river Tees where SABIC has a processing plant and jetty facilities. Whilst there was some localised flooding, it was considered to be manageable in context of the flood preparations that had taken place. Hence by early evening, the Site was moving into clean-up mode and, returning to normal operation. What happened next was unprecedented, unforeseen and not planned for in any flood damage assessment or Seveso Major Accident scenario.

At approximately 11pm, whilst undertaking a routine tour of the Brinefields and Cavities area, a process technician heard a large crashing sound and observed what he later described as a tsunami like wall of water coming from Greatham Creek and heading toward the Brinefields and Cavities area which stores thousands of tonnes of hydrocarbon in underground salt cavities. Fortunately the technician was in a safe location away from the incoming water.

The Site Alarm was raised immediately and the cavities placed into a safe operating condition by closing the Remote Operated Shut-Off Valves. It was extremely difficult to make a full damage assessment in the darkness so the decision was taken to cease all hydrocarbon movements to and from the area. This decision not only affected operations within SABIC but had immediate consequences for other local businesses that have infrastructure and product storage within the area.


Figure 6 : Control room on the Brinefield – note flood level mark on control room wall, Source Sabic UK Ltd

SABIC has a Crisis Management protocol that is brought into action following incidents that have the potential to cause significant societal impact or business impact. On the early morning of the 6 December, the Crisis Management Team convened. It was clear that a number of Seveso Major Incident scenarios were feasible given the initial damage assessments and that SABIC would need to be directly involved with the broader flooding incident management that was being co-ordinated by Government Agencies. Contact with the Local Authority Emergency Control centre was established and recovery operations started.

Site recovery

From SABIC's perspective the simplified view of the major emergency centred on two main objectives, these being:

1. To maintain safe containment of the hydrocarbon inventories whilst the flood defences are being repaired.

2. To safely return the area back to operation as soon as practicable without endangering people or the environment.

In a reasonably short period of time, SABIC was able to establish a routine of damage inspection during low tide. This enabled integrity assurance of the operating area and a limited amount of damage assessment to be made. What became apparent was that all the equipment containing materials under pressure was secure and that there had been limited damage to the cavity wellheads and piping infrastructure. The major damage sustained was to the electrical distribution, instrumentation and control systems including all telemetry networks. What followed were 5 months of intense electrical and instrumentation repair and replacement work whilst controlling the risks and hazards associated with working within and eventually returning to service under normal management arrangements.

The SABIC insurance loss assessment was in excess of £10 million (including both asset replacement and business losses).

Discussions are ongoing with Government Agencies regarding the ongoing integrity of the established flood defences in the Teesport Area.

IMPACTS ON SITES ON HUMBERSIDE

Inter Terminals, Immingham

Site description

Inter Terminals, Immingham, is located on the south bank of the River Humber. The site provides bulk liquid oil and chemical storage in above ground storage tanks with facilities to carry out import/export operations associated with shipping, road vehicle, rail and pipeline transfers. It is an upper tier Seveso site and also operates IED storage operations.

Preparations for flooding

The Terminal was situated in a highly vulnerable flood location and a flood risk assessment had been carried out; site plans with topographical information were available. Emergency response plans and evacuation plans were in place and some employees were registered for flood warnings. The river defence protection level was approximately 6.0m AOD, but the dock entrance level was only 3.37m AOD

During the run up to the 5 December, several flood warnings were received with predicted increased tide levels as a result of the potential storm surge. Terminal operations including shipping, road loading and pipeline transfers continued during the week.

Just prior to the flood, precautions were taken to protect key equipment as much as possible and to restrict transfer operations. Hours before the flood, it was reported that the Teesside terminals had been badly hit by the surge and that the surge was heading southward. The site landlord, Associated British Ports (ABP), was also issuing its own alerts based on different information, with confusion between Chart Datum, Ordnance Datum and tide table data. All operations were ceased and soon after electrical power, supplied from ABP, was isolated. All systems were made safe and non-key staff evacuated. Safe refuge was identified in the upper floor of the operations office for the remaining staff.

The flooding on 5-6 December 2013

The surge caused a rise in the river level to 5.1m AOD which overtopped the dock entrance gates and filling the dock until it overflowed into the dock estate. The terminals were flooded up to 1m deep from the opposite side to the river via the dock entrance. The embankment protection itself failed in several areas causing a further flow into the terminal.

None of the tank bund walls were overtopped and the bunds remained dry throughout the flood. Although mobile plant equipment was floated, there was little mechanical damage to infrastructure. All ABP and site switchrooms were flooded and the waste water treatment was rendered inoperable, but there was no loss of containment of any product.

Short term site recovery

The level of the site allowed most of the flood water to recede to the river and dock. After receiving authorisation from the Environment Agency, residual flood water was pumped back into the river. Electrical power remained off in the short term but mobile generators provided essential utility power. The terminal remained substantially inoperable during this immediate recovery period. Priority systems were eventually regained after extensive remedial works had been undertaken to key mechanical and electrical infrastructure but temporary power remained in place.

Long term site recovery

Electrical infrastructure were badly affected and temporary power enabled priority systems to be brought back on line. The site was surveyed for damage to any primary containment systems. A post flood review was undertaken which brainstormed events leading up to and during the flood to gain learning points. Eventually, after each switchroom had been overhauled and tested, full power was regained.

The main offices which saw the maximum flood depth were also overhauled and brought back into service.

Meetings with ABP and other dock users have resulted in a major undertaking to raise the outer dock entrance gates to gain a protection level of 6.5m AOD which stands a 0.1% (1 in 1000 year) likelihood of being exceeded in any one year.

CEMEX UK

Site description

South Ferriby cement works is located approximately 1.5km west of the village of South Ferriby in North Lincolnshire and is one of three cement producing sites making up CEMEX UK Cement. The plant has the capability to produce approximately 700,000 tonnes of cement per annum and directly employs 122 people, many of whom live in the surrounding area.

The site is operated under an Environmental Permit and Greenhouse Gas Permit, both issued by the Environment Agency. As such, the site has regular contacts with the Environment Agency at various levels, and these contacts helped with the awareness of event to come.

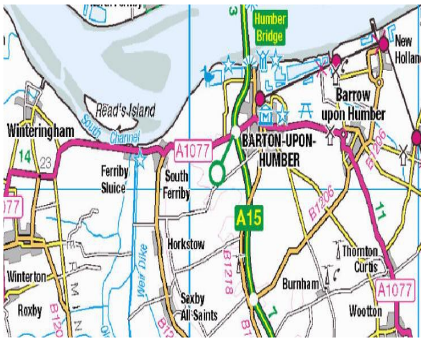


Figure 7 : Location of Chemex UK, source Environment Agency

Preparations for flooding

During the week before, the cement works was prepared for a minor flood – sandbags etc. despite being told that the site should not be affected. The cement works was in an amber warning area on the 5th December 2013. However, as soon as it became apparent that there was a high risk of flood defences being breached along the Humber, the local internal incident management team and UK rapid response team were established and flood contingency plans were put in place.

As a top priority, health and safety, all non-essential employees were sent home, shift times altered and those on site stayed in safe positions. Mobile machinery and plant was moved to higher ground where possible. Power was cut to operations when it was clear sub-stations would be threatened and shutdown of the cement kiln was initiated. Containment of oils and waste fuels was implemented to minimise potential loss. All contingency plans worked and support was provided to the local village in evacuating and preparations, albeit for a minor flood.

The flooding on 5-6 December 2013

At 6.44 pm hours on 5 December, the flood defences on the Humber Estuary were breached and the site was inundated with flood water from two directions. Fortunately, all employees were safe with the final three employees being rescued from site by the emergency services.
Despite the activation of the flood contingency plans, the breach was much greater than expected and the entire site was submerged in water with flood waters being up to 3 metres in depth in places. The site lost all power and communication links.

The flood water and silt caused catastrophic un-repairable damage to control systems, the power supply network, compressed air systems, buildings and the cement kiln which was currently operational due to insufficient cooling time. High and low voltage systems were wiped out by water tracking into the terminated ends of the cables. Production was not possible due to the flooding.

All normal communication channels were lost leading to the use of social media, to provide a direct an reliable communications channel for all employees, and temporary offices were installed in a cabin at the unaffected nearby quarry. Most of the workforce was kept off site for up to three weeks whilst the site was professionally cleaned, decontaminated and made safe.

The site was without electricity for many weeks and production did not start until the summer of 2014. The main lesson learned was to protect electrical systems such as transformers from flooding by building walls around them or raising them above the level of flood water.

Source CEMEX ARR

Site recovery

Site recovery has been extensive, initially involving cleaning and removal of unsafe structures along with implementing plans to ensure customers could be supplied with cement from the other CEMEX UK Cement sites.
Re-commissioning of the site commenced late in November 2014, nearly a year before the first anniversary of the flood.

Repairs have involved significant time and investment with up to 400 contractors on site at any one time. They included the installation of new primary sub-stations, a new compressor building, a new control room, 6.4 kilometres of new high voltage cables, with none of the original high voltage system being reusable, along with low voltage and control cabling and 22 metres of new kiln shells. 86 skips of electrical equipment alone have been removed from site.

Cement works such as South Ferriby are very capital intensive, with new sites costing several hundred million pounds with operational lives typically over 40 years. The current systems at South Ferriby had been operational since the 1970's and as such, much of the equipment that was damaged in the flood was no longer directly replaceable. Recovery costs to bring the site back into operation are therefore very high, tens of millions pounds.

Flood defences managed by the Environment Agency have been repaired along the Humber with discussions ongoing to implement further defences for the village of South Ferriby.

On site, wherever possible, cables and equipments have been elevated to 2 metres above ground level. For example the new compressor building, as shown on the picture has been built on concrete plinths.

Source Environment Agency

LESSONS LEARNT

Risk assessment and Planning

On the 5 December 2013, a combination of spring high tides and a deep depression caused a tidal surge in the North Sea that affected the UK coast from Scotland to Suffolk. In places, this was more severe than the similar event which occurred on 31 January 1953 which is now considered to have been the worst peacetime disaster ever to strike Brittan. The consequences of the 1953 flood were even more severe in the Netherlands. Since 1953, considerable effort has been put into flood risk assessment, flood defences and planning. The effect of these can be seen in the adjacent table.

	1953	Dec 2013
Breaches	1200	2
Properties Flooded	24,000	1,400
Deaths	307	2, not flood related
Agricultural Land	65,000 ha	6,800 ha
People evacuated	32,000	18,000
Infrastructure	2 Power Stations	Impacts on Industry on Teesside and operations at Immingham Port
Flood Warnings		71 severe flood warnings. Over 160, 000 warning messages sent directly to homes and businesses

As a result of the December 2013 flooding, it is now recognised that:

- Many major hazards sites are located on an indicative flood plain and are therefore susceptible to river, sea or tidal flooding. These locations were deliberately chosen because they provide level building land, access to good transport links, a supply of cooling water and a discharge route for liquid effluents);
- Many sites were built during the 1950s and 60s and the flood defences provided at the time might not be adequate to protect against the anticipated effects of sea-level rise and climate change;
- Many sites have never experienced flooding hence flood risk might not have been properly addressed as part of the on-site and off-site emergency plans;
- Flooding of major hazards sites could lead to the loss of containment of dangerous substances and have a significant effect upon the environment. Pollution could affect the water courses themselves, adjacent sensitive habitats and necessitate closing drinking water intakes with consequent disruption to public water supplies;
- Flooding could also have significant financial and operational implications for the site concerned. It could lead to some operators going into receivership, leaving the Agency and Local Authorities to deal with land contamination and clean-up issues.

The Environment Agency did not have Seveso site plans readily available for Incident Management use, which created some confusion during the first few days after the storm surge. This is being addressed by putting the Seveso site boundaries and site entrances data onto the EA Incident Management mapping system.

The Environment Agency supports operators with a range of products and services to ensure they can meet their obligations to manage flood risk for their sites:

- The Environment Agency and the Met office jointly operate the Flood Forecasting Centre (FFC), to provide daily flood risk guidance for England and Wales. A similar service operates in Scotland with SEPA;
- The Environment Agency operates an extensive river flow and sea level monitoring network, the results of which are available online;
- A series of computer models are available and used by the Environment Agency for local flood forecasting including for tidal sites;
- Publication of indicative flood plain maps on the internet;
- Publicity campaigns to increase public awareness and to encourage at-risk stakeholders to develop a flood plan;
- A system of automated telephone messaging to disseminate flood warnings.

The UK Government recognises that a wide area coastal flood is one of the most significant natural hazards facing the UK. More serious events have the potential to seriously stretch local responders and resources. The Government's Coastal Flood Group Response and recovery guide was revised in November 2014 following the country's learning from the December 2013 floods.

National Flood Defence Repairs

The Environment Agency is also responsible for planning, constructing and maintaining the critical flood defence infrastructure for England. Since the 1953 floods, drainage work was carried out on many rivers, many flood defence banks were built and the Thames Barrier was completed in 1982. The Environment Agency is currently responsible for the expenditure of about £500m/year on new and improved flood defences throughout the country. To enable the Environment Agency to do this effectively, it has a sizable team of specialist engineers who were available for redeployment for the emergency repairs that became necessary following the December 2013 flooding. A number of major flood defence projects were scoped, planned and implemented between 06 December 2013 and 02 January 2014 when the next extremely high tide was expected. The UK Government authorised a total of £30m emergency funds in the days following the flood for this work to be undertaken.

Learning for Industry

- It must be recognised that flood defence structures can fail completely during a flooding incident; walls and embankments might be over-topped or collapse under the weight of water or flap valves and sluice gates might not close properly.
- The site emergency plan should include a Layers of Protection Analysis (LOPA) which considers flood defence structures to be simply one layer of protection. If a flood defence structure fails, other layers of protection should be capable of preventing a major accident and avoiding the site going out of business.
- Flood risk assessment and emergency plans should be reviewed on a regular basis to ensure they are up to date. For example there were a few sites that had registered to receive flood warnings but did not receive an automatic warning because the site staff had moved into new roles, site telephone numbers had changed or the warning was sent to the wrong location.
- The site flooding emergency plan should use the Environment Agency flood warnings as trigger points to initiate the different stages of the plan.
- Emergency exercises with a flooding scenario have a vital role to play in ensuring an effective response to a flooding incident.
- Sites should consider the need to relocate existing safety critical equipment and to install new build above the maximum flood level.
- Electricity supply in an emergency must be considered. One of the biggest difficulties faced by the sites during the initial recovery phase was the lack of an electricity supply. This was a particular problem in December and January because there were only 8 hours of daylight.
- Storage tanks containing small inventories should be partially filled to prevent them from floating when surrounded by flood water.
- Floating objects can cause significant damage when they are swept along by flood water and collide with other fixed infrastructure. Any objects that can float should be secured or removed from site as part of flooding preparations.

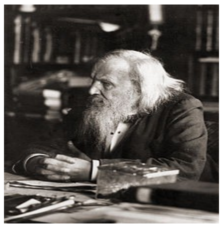
The joint Environment Agency / Chemical and Downstream Oil Industries Forum (CDOIF) guidance note on preparing for flooding at IED and Seveso sites has been revised to include all the lessons learned during the December 2013 event. The guidance is published on the CDOIF Section of the Health and Safety Executive (HSE) website .

Theme 6

Pipelines

Pipelines

An older technology, the first pipelines to carry hazardous materials or pollutants were introduced in the United States during the 1860's. The inventor of the periodic table of the elements (D.I. Mendeleïev)[1] was in fact an active participant in their development by improving the concept favoured in ancient Rome of conveying water by means of gravity (aqueducts).
Today, millions of tonnes of oil and chemical products, along with billions of m³ of natural gas, are routed every year through the French pipeline transport network, whose characteristics will be recalled below.
As a highly means of transport with a lower risk of accidents than the alternatives (road, rail, waterway), pipeline use still entails a number of risks, notably in the case of a leak or burst along the line. The loss of fluid being channelled can lead to hazardous phenomena of the type: fire or explosion with thermal and pressure surge effects in the presence of flammable gases or liquids; and pollution of the soil, subsoil, water table and watercourses.



D.I. Mendeleïev
Use of tubes in transporting hydrocarbons

Primary indicators

The French network

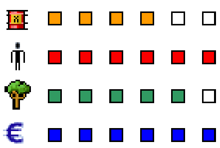
Total length of the French network of pipelines for transporting hazardous products equals 50,000 km, with an average age of 40 years and a breakdown as follows:

- 73 % Natural gas (36 500 Km)
- 19 % Hydrocarbons (9 500 Km)
- 8 % Chemical products (4 000 Km) ethylene, oxygen, hydrogen, brine, etc.

These pipeline segments mostly run underground, except for the instruments necessary for their operations (stations dedicated to pumping, compression, expansion, isolation, interconnection). 25% of the routes of such facilities cross a designated nature reserve or an ecologically sensitive zone.

1. Accident study

The ARIA database catalogues 309 events recorded on French pipelines between 1 January 2006 and 31 December 2013. The primary accident occurrence indicators (breakdown of accidents on the basis of products transported, causes and consequences are presented in a summary table on page 2. These events involve steel pipe sections (along the transport lines) as well as their ancillary installations (pumping stations, compression stations, scraper stations, etc.). Another 70 foreign events were also catalogued over this same period for the important lessons they provide. Such is the case for the Marshall accident, considered one of America's most noteworthy events (ARIA 44816), or Germany's Wesseling accident (ARIA 43139).



ARIA 44816 - 25 July 2010 - MICHIGAN - United States
A pipeline transporting crude oil extracted from the Alberta (Canada) tar sands and heading into the U.S. burst over **a 2 m length**. This rupture occurred during a planned facility shutdown operation.
Over nearly 17 hours, **3,800 m³ of crude oil spilled into the ground before polluting the KALAMAZOO River via the TALMADGE stream**. A corrosion problem caused this accident.

[1] "The essence of materials for engineers", Robert W. Messler - page 499.

Analysis of 309 French accidents between 1 January 2006 and 31 December 2013	*Nb accidents*	*%*
Products transported		
Natural gas	*190*	*62*
Including ancillary installations	*112*	*36*
Liquid hydrocarbons	*37*	*12*
Including ancillary installations	*12*	*4*
Chemical products (ethylene, hydrogen, oxygen, etc.)	*82*	*26*
including brine ducts	*58*	*19*
Consequences (not mutually exclusive)		
Fatal accidents	*2*	*>1 %*
Accidents with injuries	*8*	*3*
Pollution incidents	*41*	*13*
Causes (not mutually exclusive)		
Corrosion	*59*	*19*
including brine ducts	*33*	*11*
Works adjacent to pipeline facilities	*52*	*17*
Physical malfunction : weld, tube shape defects, etc.	*15*	*5*
Natural causes : lightning, frost, etc.	*20*	*6*

Works in the vicinity of pipelines constitute the major cause of accidents recorded, when focusing on leaks in the lines and when excluding ancillary installations and cases of brine duct corrosion. The same scenario tends to be repeated: during construction taking place independent of the pipeline, earthworks equipment damages or punctures the facility. Organisational deficiencies often lie at the source: no preliminary regulatory filing (works programme declaration and/or declaration prior to commencing works), lack of familiarity with the rights-of-way inherent in running a pipeline, and difficulties in communication among the various actors.

Equipment malfunctions mainly pertain to defective welds. A series of accidents has also exposed problems with ancillary components like: flange joints, isolation devices, valves, pump seals, and check valves.

Moreover, corrosion is the source of many cases of pipeline leaks or longitudinal breaks. The events catalogued principally involve the following:

- external attack on pipe segments or their supporting elements as a result of environmental characteristics;
- defects in the facility's cathodic protection or protective lining;
- internal attack on tube walls due to the physicochemical characteristics of the fluid being transported (frequently encountered for brine).

Aggressions from natural sources have involved lightning strikes, landslides and structural excavation work subsequent to flooding. Intense cold waves are also correlated with the occurrence of accidents as they adversely affect the operations of check valves installed at expansion stations on gas pipelines; moreover, cold fronts initiate freezing/thawing phases in the products being transported, which in turn induce mechanical stresses capable of causing the line to burst.

2. Characteristics of pipeline leaks and ruptures

The ARIA database contains 157 cases of line leaks or breaks (with the length of the opening exceeding the pipe diameter) occurring over the linear section of facilities between 1 January 2006 and 31 December 2013 (excluding ancillary installations). This figure represents an average of 20 leaks per year, which corresponds to averages derived from the other professional databases, whose range varies from 20 to 25 leaks a year. France is positioned around the European average, as indicated by the following data:

Comparison among databases

Primary indicators

ARIA 2006-2013, gas (excluding ancillary installations / French line length): 2,2.10-4 /km.year
ARIA 2006-2013, gas (including ancillary installations / French line length): 5,9.10-4 /km.year
EGIG 2006-2010, gas (excluding ancillary installations / European line length): 1,6 . 10-4 / km.year
EGIG 2006-2010, gas (including ancillary installations / European line length): 2,8 . 10-4 / km.year

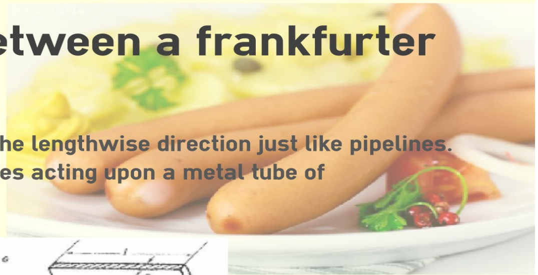
ARIA 2006-2013, hydrocarbons (excluding ancillary installations / French line length): 2,4.10-4 /km.year
ARIA 2006-2013, including ancillary installations / French line length: 3,7.10-4 /km.year
CONCAWE 2007 - 2011, excluding ancillary installations / European line length: 2,4 . 10-4 / km.year
CONCAWE 2007 - 2011, including ancillary installations / European line length: 3,3 . 10-4 / km.year

ARIA 2006-2013, brine ducts (French line length): 17,5.10-4 /km.year
ARIA 2006-2013, chemical products (French line length, excluding brine): 6,2.10-4 /km.year

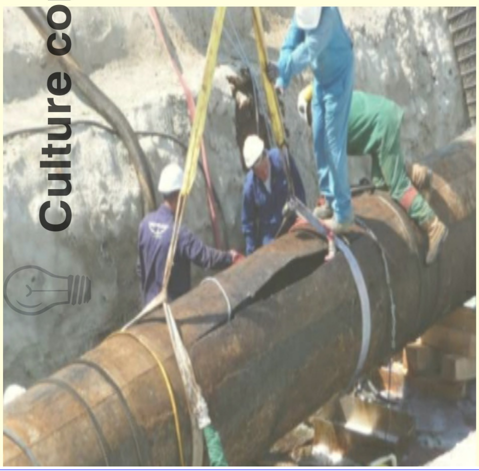
The trend in leak causes over the past 5 years seems to be moving towards a higher proportion of accidents tied to installation ageing (corrosion, defective welds, fatigue, etc.) and less damage due to neighbouring utility works. Over the past 5-year period, 8 cases of pipeline rupture have been recorded.

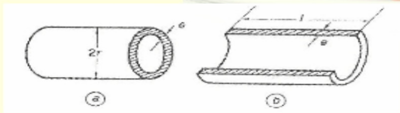
Culture corner

What's the difference between a frankfurter and a pipeline?



When cooking frankfurter, they always break in the lengthwise direction just like pipelines. This phenomenon may be explained by the stresses acting upon a metal tube of thickness e subjected to pressure P :





Transverse rupture (a) and longitudinal rupture (b) of a pipe subjected to internal pressure.

We consider that the pipe is closed at both ends. Up until the breaking point, the stress forces are in equilibrium with forces being exerted by the pressure. The axial force due to pressure equals $pr^2\pi$, and the stress σ_{ax} acting upon the annular surface $2r\pi e$ ensures the equilibrium: $pr^2\pi=2r\pi e\sigma_{ax}$, which in turn yields: $\sigma_{ax}=(pr)/2e$. For a longitudinal rupture, pressure p acts upon the cross-section $2rl$ giving rise to the stress σ_{az} on cross-section $2el$, hence: $p2rl=\sigma_{az}2el$, which leads to: $\sigma_{az}=(pr)/e=2\sigma_{ax}$. This expression, referred to as the "boiler formula", indicates that the azimuthal stress is two times greater than the axial stress, thus drawing the conclusion that rupture always occurs in the longitudinal direction.

Extracted from the book by Istvan Berkes – Everyday physics

3. Accidents prevention in France

The set of catalogued events, including the most recent, underscore the importance of focusing more closely on controlling pipeline ageing and monitoring works taking place in the vicinity. For this reason, in 2010 the Ministry of Sustainable Development launched an obsolescence prevention plan, intended for industrial facilities and based on detailed facility assessments conducted by individual operators, in addition to overhauling the regulations applicable to jobsite safety adjacent to pipeline networks (involving a works declaration reform or damage prevention reform).

3.1 Operational monitoring

According to the Ministerial order issued on 5 March 2014, i.e. the so-called "multi-fluids order", pipeline operators are required to define **Monitoring and Maintenance Programmes (MMP)**. This obligation imposes that transporters adapt their risk control measures and reinforce actions to verify both the structural integrity and ultimate repair on networks' most vulnerable zones. The regional Directorate for the Environment and Development Agencies (DREAL) were assigned to examine the safety reports and MMP to ensure their completeness.

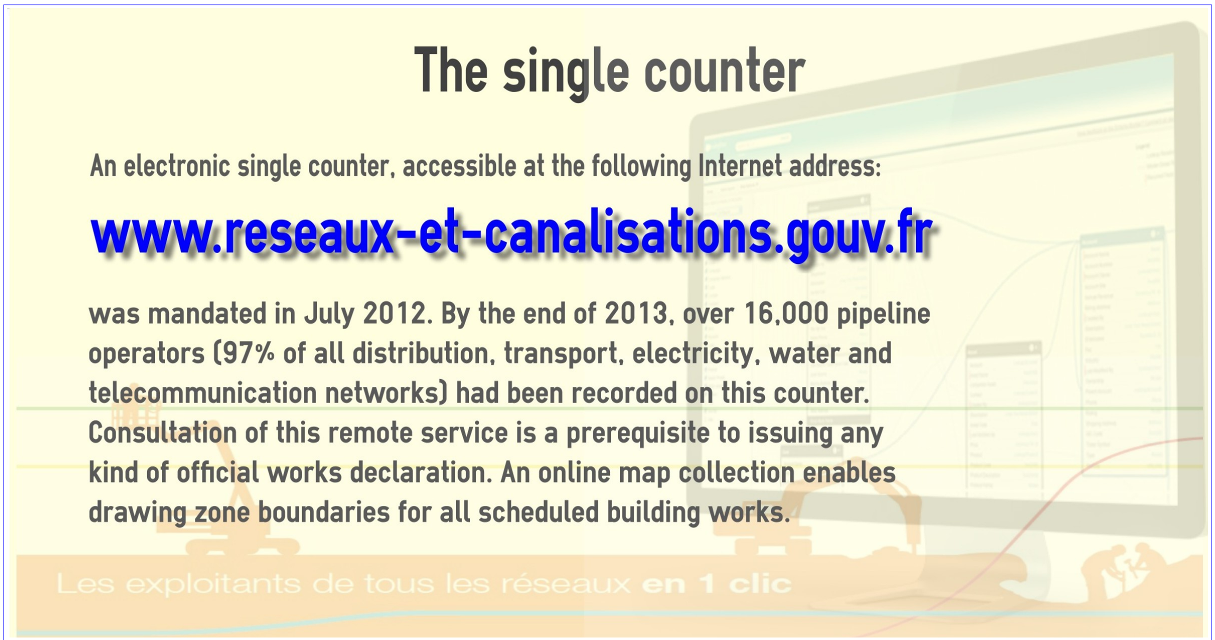
From a technical perspective, in order to avoid external corrosion of pipelines, steel tubes are lined with a waterproof protection (formerly pitch, nowadays polyethylene or polypropylene) and moreover protected by means of a cathodic system. Pipelines currently in service are monitored for the most part either by running an array of instrumented scrapers to detect various defect categories like deformation, loss of thickness, cracks (magnetic/ultrasound measurements) or shape flaws (roof effect of tubes, as evidenced during the Crau accident - ARIA 36654), or by taking electrical measurements on the surface to identify any lining defects. The relevant tubes can then be easily located, repaired, replaced, or targeted for closer supervision.

However, **the ageing of installations raises fears that the situation may become exacerbated if Monitoring and Maintenance Programmes have not been adapted to the vulnerabilities of the various pipe segments** according to the periodic evaluation of their structural integrity. Special attention also needs to be paid to those segments inaccessible to inspection: enclosed segments, presence of elbows preventing the use of scrapers or making the cathodic protection ineffective.

3.2 Damage protection reform and urban planning controls

As discussed above, works on adjacent streets and utility lines account for a major share of primary accident causes. For this reason, a single counter system has been created by the administration in order to streamline the declaration of such works and create a network among the various actors.

Other measures serve to effectively complement the urban planning control process as regards pipelines. Supervising the line's itinerary by foot reconnaissance and flyover are examples of techniques commonly employed by transporters.



Moreover, **public utility easements** specific to the set of hazards implied by existing pipelines will gradually be introduced between 2014 and 2018 so as to better control urban development projects in the vicinity of pipelines.

Rupture of a crude oil pipeline

26 May 2014

St-Vigor-d'Ymonville (Seine-Maritime) France

Release
Pipeline
Hydrocarbons
Works
Corrosion
Site clean-up
Protected natural zone

THE FACILITIES INVOLVED

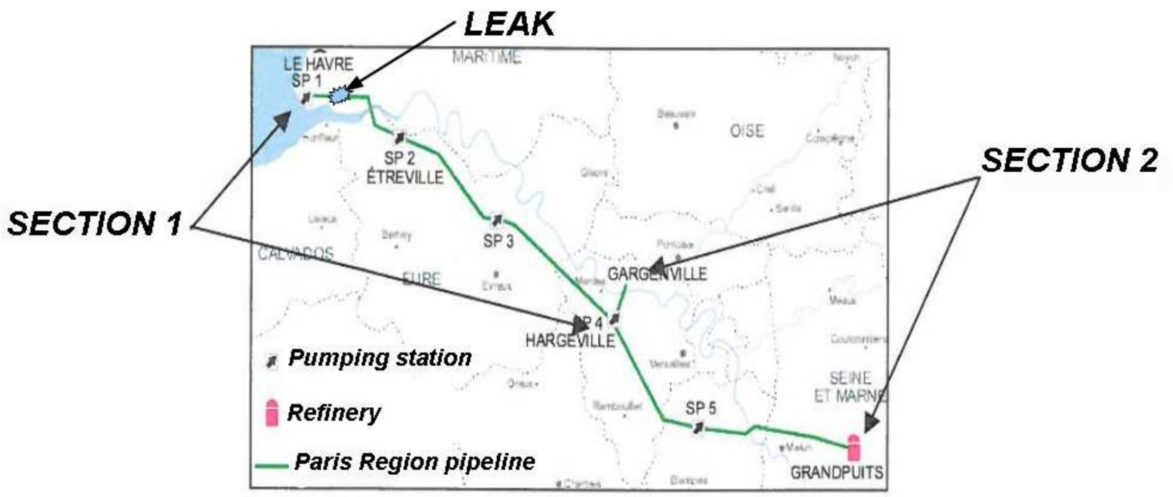
The facility involved in this accident was a pipeline called "PLIF" (acronym for Paris Region Pipeline) operated by an oil company located in Gargenville (Department 78).

The line's primary characteristics were as follows:

- nominal diameter (ND): 20 inches (508 mm);
- service pressure: 69 bar;
- year placed into service: 1965;
- buried depth: approx. 1 m in a clayey soil;
- length: 260 km;
- maximum flow rate: 1800 m^3/h;
- capacity to transport roughly 6.5 million tonnes of product annually;
- number of pumping stations: 5.

The pipeline was transporting crude oil from the Le Havre Port (76) to the Grandpuits Refinery (77) in the Paris Region. This line was also transporting finished products from the refinery to the Gargenville storage.

The leak occurred at the level of a trench running through the Hode marshland, part of which had been classified within the SEINE Estuary national nature reserve. It was actually identified 1.5 km beyond the boundary of this reserve, in the part located between pumping stations PS1 and PS2.



Copyright: Facility operator

THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

Accident chronology

6:00 am: Automatic shutdown of one pumping station (PS2) owing to low pressure readings. Shutdown of the other pumping station (PS1) by the crew foreman, followed by complete closure of the pipeline.

6:05 am: Call received from a lorry driver after seeing a geyser erupt on a field.

6:11 am: Isolation of the pipeline (closing of block valves at the Le Havre Port and around the line's SEINE crossing in Tancarville).

7:30 am: Oil company personnel arrive at the scene.

8:00 am: Activation of the External Emergency Plan, followed by mobilisation of crisis units.

9:00 am: French military police "Gendarmerie", fire department, city hall, Environment Agency representatives all on-site, installations secured.

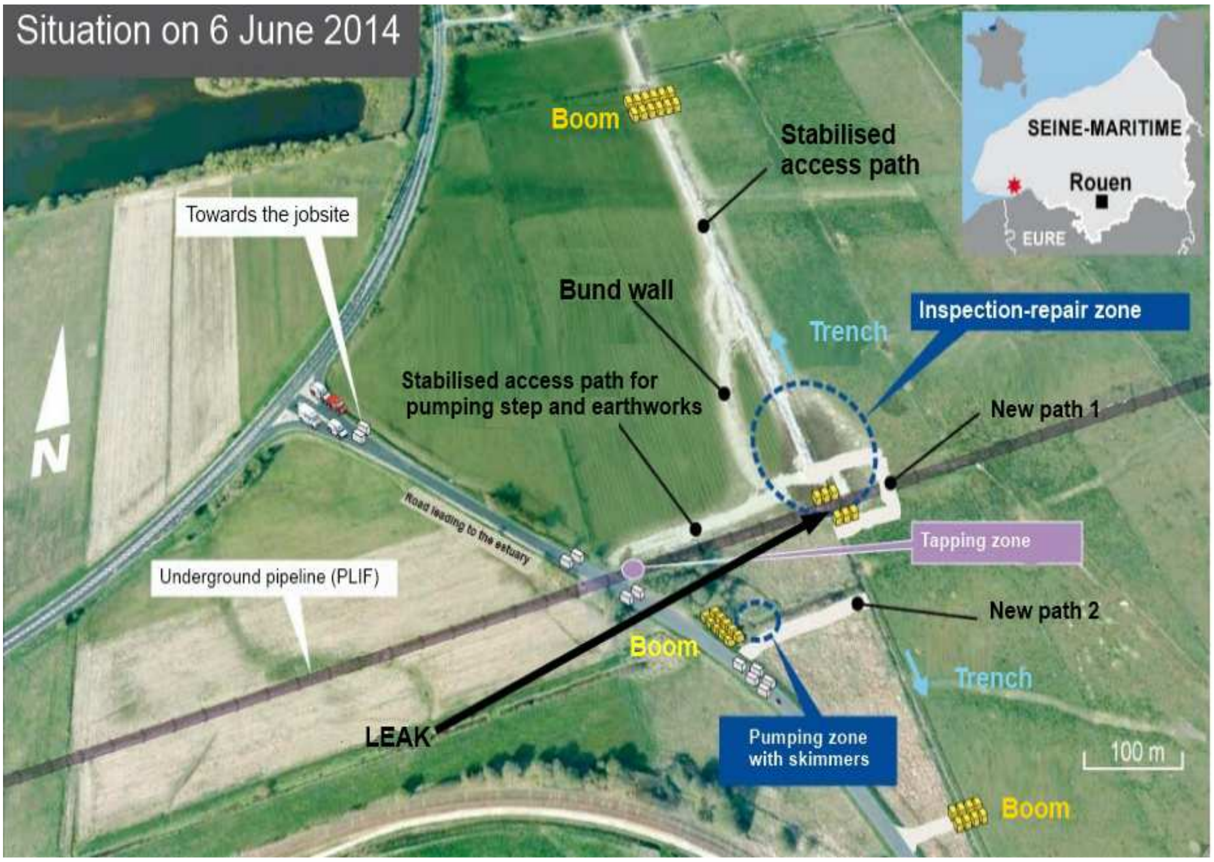
9:45 am: On-site deployment of the initial pump vehicles.

9:50 am: Issuance of the first press release by the pipeline operator.

11:20 am: Immediate protection measure adopted - deployment of oil containment booms in the trenches.

3:00 pm: Beginning of pumping operations at the most easily accessible point.

3:30 pm: Preparation of access routes leading to the northern, southern and western pumping zones, and initiation of pumping operations.



Copyright: Layout created by the pipeline operator

The consequences

Copyright: DREAL

Environmental impacts

The pipeline operator estimated the quantity of oil dispersed into the environment during the leak at roughly 500 m³.

The oil spread and fouled 820 meters of trenches (submerged at the time), with the oil pooling at the bottom over 650 meters of this length. Both flora and fauna were immediately affected by oil at the surface.

Copyright: Pipeline operator

Copyright: DREAL

The oil geyser resulted in a falling oil spray that stuck very tightly to parts of plants above ground.
14,000 m² of meadow, used mainly for the production of animal feed and beef cattle grazing, were adversely affected by the oil spill. Some 48,000 m² of surface were sprayed by oil (micro-droplets on the above-ground parts of plant life).

Via a trench, the oil also spilled into a willow plantation.

Copyright: Pipeline operator

The presence of crude oil was not detected in the groundwater.

Aquatic fauna

About fifteen dead pike, eel and crayfish were recorded.
Many dead aquatic beetles, Planorbis snails (flat rolled shells), Limnea (spiral shells), Sphaeriidae (bivalve molluscs), Odonata larvae (dragonflies and damselflies) and an adult damselfly were also identified in the trenches.
Jumping frogs could be observed on several occasions in the polluted zones.

Terrestrial fauna

Mammals, macro-invertebrates (flying insects, land-borne insects, molluscs, shellfish, beetles, spiders, worms, wood louses, grasshoppers, etc.), birds (homing pigeons) were all fouled.
Smaller traces of fouled mammals (coypus, muskrats, wild boar, roe deer) were also logged, thus indicating an attempt to flee the polluted zone. Muskrats and coypus are dependent on aquatic environments; they proceeded to dig galleries into the banks of the trenches. These galleries were totally inundated by the oil. A dead muskrat in one of the trenches and a survivor bogged down in a stretch of meadow were discovered.
A fouled pigeon was found dead; 2 others were transported for rescue to the CHENE Association in Allouville-Bellefosse (76). The owners were notified via Internet by means of the numbers on the birds' bands.
Two moorhens and a mallard were found dead, unable to free themselves from the oil.
The vast majority of fauna present at the site were in the midst of their breeding period, which encompasses spring and/or summer; this pollution outbreak caused a sizeable and direct loss of the season's reproduction by depleting the species of individuals, juveniles and embryos. Afterwards, the pollution clean-up effort represented a constant nuisance, lasting several months through the end of the reproductive period. The species experiencing the greatest impact were most likely bats and small mammals, whose habitat adjoined the affected zone.
Beef cattle potentially grazing in the vicinity were kept away from the pollution source.

Economic impact

Throughout this pollution incident (spanning clean-up, repairs, rehabilitation and monitoring), the pipeline operator enlisted assistance from:
- 60 subcontracted firms and partners with a stake in the effort;
- 100 individuals;
- 20,000 hours worked over a 5-month period.

The total cost of this incident was on the order of €8.5 million, including direct and indirect expenses.

European scale of industrial accidents

By applying the rating rules applicable to the 18 parameters of the scale officially adopted in Ferbruary 1994 by the Member States' Competent Authority Committee for implementing the 'Seveso' directive on handling hazardous substances, and in light of information available, this accident can be characterised by the four following indices :

The parameters composing these indices and their corresponding rating protocol are available from the following Website: http://www.aria.developpement-durable.gouv.fr

The "Environmental consequences" index was rated "3" since a 6.4-ha ground area had been polluted "parameter Env13".

The "Economic consequences" index reached a "4" due to the cost of environmental clean-up, decontamination and rehabilitation, which were valued at over €1 million "parameter €18".

The "Hazardous substances released" index was not scored since crude oil is not among the products listed in Appendix 1 of the Seveso 2 Directive in effect at the time of the accident. Moreover, no human or social consequences were reported.

THE ORIGIN, CAUSES AND CIRCUMSTANCES OF THE ACCIDENT

The oil leak occurred subsequent to the widening of an 87 cm long opening positioned along the upper generatrix of the pipeline on both sides of a circular coupling weld between two rolled-welded tubes. The longitudinal welds on this pair of tubes were located away from the rupture zone. An approx. 4 meter length of pipeline was removed and appraised by an expert. The section of burst pipeline displayed along its upper generatrix many signs of shock, dents and scratches as well as macroscopic deformation in the form of flattening and ripples. The outer surface of the circular coupling weld was also damaged, thus indicating that the damage occurred after installing and welding the tubes.

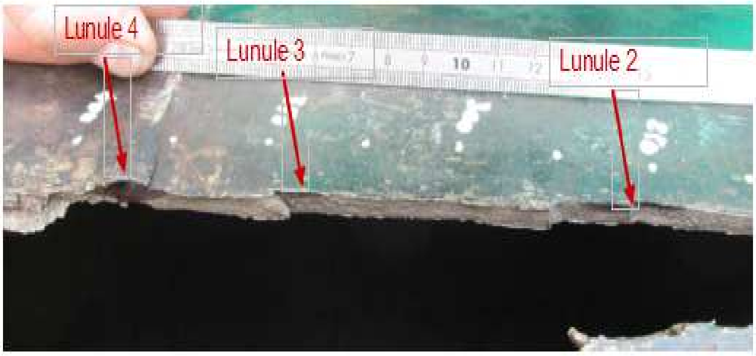
The morphology and location of this external damage reveal that it was probably caused by heavy equipment, subjected to a scraping effect from a power shovel and/or a track roller crossing over the ground.

Copyright: Pipeline operator

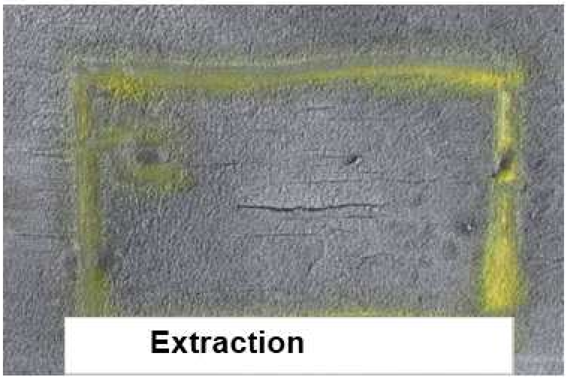
The tube appraisal conducted by an inspection body established that the sudden pipeline break, followed by gradual development of multiple longitudinal corrosion cracks due to stress, was initiated from the outer skin of the pipeline, in the strain-hardened zone with mechanical deformation.

Inside the rupture zone, six lunula corresponding to pre-existing longitudinal cracks representing some 35% to 50% of the wall thickness could be identified. These lunula were characterised by an advanced state of oxidation, or even corrosion, that did not match the ultimate rupture zones and moreover proved that they predated the actual rupture. The presence of radiating bands from the external surface suggested crack onset from this surface. The remainder of the pipeline surface offered a clean appearance without any loss of thickness due to corrosion. Furthermore, no corrosion on the tube's internal surface could be detected.

Copyright: of these images Pipeline operator



Outside the rupture zone, on the outer surface of the liner and along the upper generatrix, the magnetic particle inspection evaluation revealed the presence of crack-type anomalies associated with the identified mechanical damage that had strain-hardened the metal and caused the tube to flatten over its upper generatrix. Mechanical stresses at the level of the connection with the non-flattened zone had thus formed.



Inspections conducted on the pipeline prior to the accident

Since the pipeline was over 30 years old (50 years since its inauguration), the mandatory comprehensive assessment within a period of less than 6 years had been respected. The inspections performed on the pipeline had been as follows:

2013: Running scrapers - geometric and thickness measurements + crack detection. The definitive reports had been transmitted to the oil transport company by the commissioned inspector just before the accident;

2009: Inspection conducted by the tube lining contractor by means of measuring the electric potential gradient (known as the Direct Current Voltage Gradient, or DCVG, method);

2008: Running scrapers - geometric and thickness measurements (by the assigned inspector).

These inspections and, more specifically, the reports submitted to the transporter never mentioned unacceptable tube degradation at the level of the rupture. The measurements recorded in 2008 and 2013 by scrapers however revealed both the existence of tube deformation far below the acceptance criteria (1.2% of the ND, for a tolerance set at 6%) and a collection of defects that were identified as a field of inclusions (metal impurities, typically without any consequences).

Following expert appraisal of the pipeline liner by a specialised organisation and a repeat analysis of scraper data (an in-depth assessment of results), it was revealed that the visible ripples on the tube's upper generatrix most likely caused a rebound or too steep of an incline for the ultrasound sensors on the crack detection scraper, thus leading to a discontinuous reading of the crack responsible for initiating rupture. This situation yielded a poor interpretation of results, as the analyst had drawn the conclusion of a field of inclusions instead of a crack.

Subsequent to the DCVG measurement campaign conducted in 2009, no loss of tube liner had been reported around the defect. Nonetheless, the damaged section displayed considerable pieces of the original (pitch) liner missing, which was a requisite condition for the appearance of corrosion zones, as the expert had noted. This point remained unexplained.

ACTIONS TAKEN

Following the accident, the main concerns focused on containing the pollution and undertaking clean-up works as a means of reducing impacts on the natural environment. Moreover, the resumption of facility operations with sufficient guarantees relative to the line's structural integrity, to avoid having to shut down the Grandpuits refinery, was another concern.

For this purpose, on 27 May, the Seine-Maritime Department Prefect signed an emergency executive order:
- requesting the pipeline operator to adopt measures limiting the spread of pollution;
- supervising the resumption of pipeline service (subject to: completion of a report on the accident causes, release of the most recent pipeline inspection reports, statement of anticipated repairs, proposed restart conditions, etc.) and submitting the resumption plan to the proper oversight authorities for approval.

Measures adopted to eliminate the pollution threat

As of the morning of 26 May, the pipeline operator installed containment booms in the trenches and initiated pumping at the points easiest to reach.

During the afternoon of the same day, the oil company began preparing access routes (through a marshy zone) to clear the way for heavy machinery and pursue pumping operations.

The pollution was completely confined using earthen dams reinforced by an impermeable membrane. Fences and anti-amphibian screens were installed to prevent local fauna from entering the polluted zone.

The 4500 m^3 of crude oil, water and sediments pumped from the zone were discharged at the Normandy Refinery site (located a few kilometres away), where a settlement protocol had been implemented specifically to manage this accident. These 4500 m^3 included the 2100 m^3 of crude oil resulting from the pipeline drainage step prior to its repair.



Copyright: Pipeline operator

Surface water monitoring was introduced outside the confined zone, while groundwater verifications relied on the deployment of 4 piezometers.

To clean the willow plantation, the FOST (Fast Oil Spill Team) unit was contacted for assistance. This unit is a Marseille based skills centre affiliated with the oil company; it offers trained response teams along with a ready supply of equipment for eliminating hydrocarbon pollution.

A remediation plan was drawn up under the aegis of representing CEDRE (Centre for Documentation, Research and Experimentation on accidental water pollution, created in 1979 subsequent to the Amoco Cadiz shipwreck) and in collaboration with competent authorities; its contents were based on the following principles:

- mowing and clearing of zones affected by sprayed crude oil;
- production of a topographic map of trench bottoms and meadows, yielding the profile to follow during rehabilitation work;
- rehabilitation of the designated drainage trenches;
- stripping of topsoil and potentially deeper in order to limit the contributions of non-native soils as much as possible;
- filling of excavated zones in conforming to the initial topography, with earth imported from a neighbouring zone (avoiding the hauling of non-native soils);
- acceptance of all works performed with CEDRE and in the presence of recognised competent authorities.

This remediation plan was associated with an established monitoring programme dedicated to local groundwater, flora and fauna.

Pipeline repairs

Repairs to the pipeline involved cutting out the liner, including the opened length, and replacing the missing section by new tubes. Prior to performing this operation, it was necessary to place a tap on the pipeline around 100 m from the leak to allow proceeding with the drainage step (2100 m^3 of crude recovered). Special precautions (explosion meter measurements, sprinkling, and presence of a response team) were required to prevent risks during the cut-out works. Pumping down the water table lasted throughout the duration of this programme in order to maintain access to the zone.

A steel duct was installed at the site of the trench crossing, thus providing mechanical protection for the pipeline, while avoiding any repeated damage to the facility (during completion of the pollution removal mission, trench cleaning, etc.).

Copyright: Pipeline operator

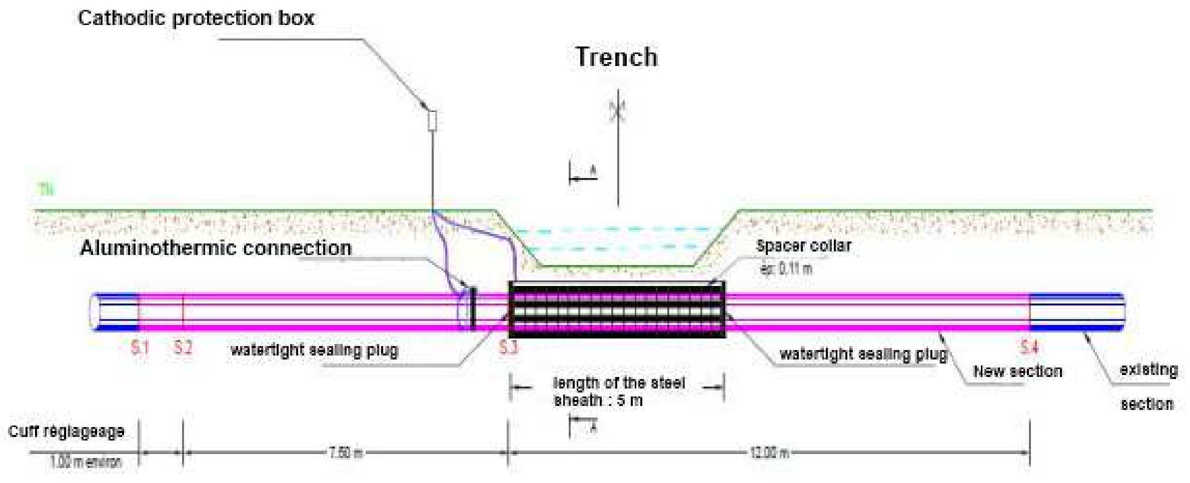


Diagram Pipeline operator

Resumption of pipeline service

In exchange for issuing their approval to resume pipeline service, the DREAL Environment Agency requested that the operator submit proof that:

- no defect similar to the one that caused the rupture was present at any spot along the entire pipeline. As such, the full set of scraper data was reanalysed by the subcontractor responsible for performing the scraping in 2006 and 2013. No signal comparable to that recorded around the leak could be identified along the remaining pipeline;
- the series of degradations recorded during scraper inspections carried out at the end of 2013 (denting, loss of thickness, cracking) was acceptable given the level of pipeline pressure and applicable regulatory criteria.

To satisfy this requirement, the oil transporter, assisted by a new service provider, prioritised all defects recorded over the entire pipeline, after conducting a new more detailed analysis of the raw scraper data for some of these defects. Based on this prioritisation step, the pipeline operator devised a digging program split into several phases, beginning with the most serious defects. This strategy enabled restoring pipeline service gradually (with pressure being incrementally increased in the line as the inspection campaign and necessary remedial works were completed).

In light of the items mentioned above (i.e. slight deformation in pipeline roundness leading to the appearance of cracks and potentially a leak), the operator ultimately decided to investigate by uncovering any dent exceeding 2% of the nominal diameter (even though the regulatory tolerance stood at 6%).

LESSONS LEARNT

The search for cracks by scraper is a technique rarely practiced by pipeline operators. This type of control is expensive (reaching several hundred thousand euros); moreover, the technology is still nascent and undergoing constant evolution. Also, interpreting the results requires a special skill set.

In looking for cracks over the entire pipeline length in addition to running the other types of scrapers and conducting a DCVG control, the transporter had made use of the most efficient state-of-the-art techniques in performing the inspection campaign.

Upon examination of just the crack detection scraper data, it was very difficult to suspect the existence of cracks at the level of this rupture. However, cross-referencing these scraper data with readings from scrapers used to record geometric measurements and thickness (presence of dents and ripples on the upper generatrix) would have perhaps alerted the analyst to the potential existence of a critical defect. It thus seems important for the interpretation of data stemming from an inspection to be cross-correlated with available data derived from other controls. An adapted methodology needs to be developed for this specific purpose.

It also seems relevant to revise or complement the acceptance criteria established in the GESIP guide dedicated to dents (<6% of the tube's nominal diameter, 2% around the welds), in particular whenever deformations lie in the upper part of the pipeline. In the present case, the deformation only amounted to 1.2% of the nominal diameter, yet this was sufficient to trigger the appearance of multiple cracks that ultimately caused the leak. In the context of a combined defect, GESIP guide criteria were no longer applicable. Once a dent is detected, given its position and size, an appropriate response would apparently be to dig a trench for carrying out more extensive inspections from outside the pipeline so as to verify the absence of cracks, especially on older pipelines.

Lastly, this accident should lead transporters and/or service providers to recalibrate the models they use to process and interpret data.

Oil spill from a sub-surface connection pipeline

28 February 2012

Wesseling

Germany

Release
Pipeline
Hydrocarbons
Corrosion
Pollution clean-up

THE FACILITIES INVOLVED

The site

The Rhineland Refinery, located in the south of Cologne is with its crude oil processing of 16 million tons per year, the biggest refinery of Germany. It covers an area of 440 hectares. In the year 2002, the refinery was formed by fusion of two oil companies. 1600 employees are working in the refinery.

The southern factory in Wesseling (Figure 1) mainly manufactures aromatic substances, olefins and methanol besides mineral oil products. This factory has produced fuels since 70 years. These fuels and other liquid products are stored inter alia in a tank field in a south western area outside the refinery (Figure 1). The Wesseling refinery is an upper tier Seveso establishment.

Figure 1: The Refinery south of Cologne is connected to the tank field (down left) by sub-surface pipelines

The involved unit

The refinery is connected with the tank field by a sub-surface set of 8 pipelines. As they belong and are managed by the refinery, they are part of the Seveso establishment.

The single walled steel pipelines are used for the transport of mineral oil products and other fluids hazardous to the environment. Pipeline number 7 was used to transport kerosene (Jet A1) from the refinery to the tank field. At the location of the leakage it is situated about 3 to 4 meters underground in sandy soil.

Four of the pipelines including number 7 were constructed in 1942 and are without traceable permits from that time. In 1986 the pipeline was in a good state and in conformity with the valid regulations, as was certified in an acceptance test report. In 1987, a permit was given to a new pipeline for waste water within this pipeline corridor. In that permit the ongoing allowance of the other pipelines was stated. After a relevant change of the tank field in 1994, the pipeline for the transport of kerosene (number 7) was also mentioned in the permit.

To be in compliance with the German regulation on inflammable liquids that was valid at that time, the pipeline had to be equipped with facilities to compensate too high pressure and a leakage detection system. Alternatively to the latter, tightness checks had to be performed to proove no loss of containment. In addition, regularly tests of the protective cathodic potential of the corrosion prevention system were necessary.

The safety equipment of the pipelines was in compliance with the regulation. The leakage detection system was able to register 5 % of the maximum flow of 100 m^3/h of liquid which is 5 m^3/h. The latest tightness and pressure tests from 2008 and 2010 showed that there were no problems concerning pipeline 7 and the other pipelines. In addition, every 3 months tests for the control of creep leakages were performed.

Until 2007, all yearly tests of the cathodic corrosion protection system confirmed protection without error. From 2008 on this was no longer the case. At least for some parts of the pipeline the protection could no longer be confirmed.

Technical data of pipeline number 7

- Length: 800 m
- Type of pipeline: steel, single walled, sub-surface
- Maximum operating pressure: 13,8 bar
- Internal width: 100 mm
- Pump rate: 100 m^3/h
- Fluid: Jet A1 (kerosene)
- Corrosion protection: electrochemical (cathodic), bitumen layer

THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

The accident

On Saturday 25 February 2012, obvious changes of the filling level of two tanks at the Wesseling site of the refinery were observed. As cause a leakage of the connecting pipeline number 7 was assumed and verified by pressure and leakage checks. The pipeline was blocked on 26 February and discharged on 28 February. The location of the leakage outside of the tank field and the refinery was identified by noise emission analysis and verified by digging up (Figure 2). It was shown by later calculations that, over a time period of 28 days, 846 tons (or 1057 m^3) of kerosene were emitted into the soil. The leakage rate was below 2 m^3/h (0,5 l/s) and could not be detected by the installed leakage detection system because it was only able to detect a minimum flow rate of 5 m^3/h (1,4 l/s).

Figure 2: Location of the leakage (yellow dot)

The consequences of the accident

The spoiled kerosene contaminated soil and groundwater in an area of about 50,000 m^2 (5 ha). The spreading on the groundwater was only stopped after 4 remedial stand pipes were taken into action. With these stand pipes the layer of kerosene on the groundwater and contaminated groundwater are removed from the soil. Up to 1 January 2015 about 280 m^3 of kerosene were removed from the soil. For the further clean up, chemical and biological measures are under consideration.

Fortunately the ground water of a nearby drinking water works is not affected by the kerosene spill because of the opposite ground water flow direction.

The European scale of industrial accidents

By applying the rating rules applicable to the 18 parameters of the scale officially adopted in February 1994 by the Member States Competent Authority Committee for implementing the 'SEVESO' directive on handling hazardous substances, and in light of the information available, this accident can be characterised by the four following indices:

The parameters composing these indices and their corresponding rating protocol are available from the following Website: http://www.aria.developpement-durable.gouv.fr

The "Hazardous substances released" index was scored a "3" as a result of the 1057 m³ of kerosene that spilled out "Parameter Q1".

The "Human and social consequences" was set equal to "0" because no consequences of this type were observed.

The "Environmental consequences" index was assigned a "3" because of the contamnation of soil and groundwater in an area of about 50,000 m^2 "Parameter Env13".

The "Economic consequences" was left blank due to a lack of data on this indicator.

THE ORIGIN, CAUSES AND CIRCUMSTANCES SURROUNDING THE ACCIDENT

The kerosene pipeline connecting the Wesseling part of the Rhineland refinery and the tank field was protected by two different anti corrosion measures: an outside bitumen layer and an electrochemical cathodic corrosion protection system. These measures are of course without effect against inside corrosion but there is no known inside corrosion stemming from kerosene.

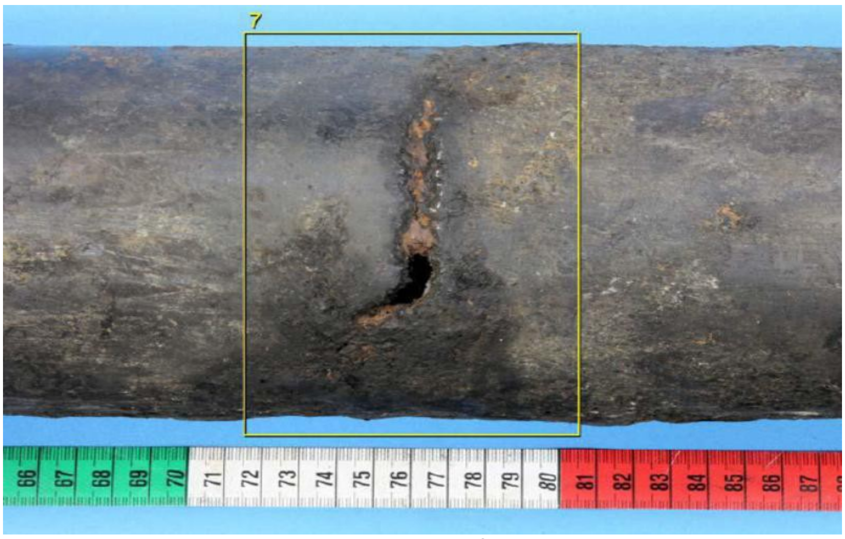


Figure 3: Hole in the steel kerosene pipeline stemming from outside corrosion (copyright: operator)

After the loss of kerosene and the detection of the leakage location the damaged part of the pipeline was brought to a laboratory for further investigation. The outside bitumen layer had been “washed” away by the kerosene flow. A hole in the steel pipe with an area of about 70 mm^2 caused by outside corrosion was found (figure 3). There were only minor signs of inside corrosion stemming probably from former more corrosive fluids transported in the pipeline but they had no effect on the integrity of steel construction.

In the direct vicinity of the kerosene pipeline, a crossing drinking water pipe was found (figure 4). It was also protected against corrosion by an outside layer and a cathodic potential. At the location of the kerosene spell there was a damage of the outside layer of the water pipe. Below the damaged layer the steel water pipe showed no signs of corrosion. In contrast to the case of the kerosene pipeline the cathodic protection against corrosion had worked at the water pipe. The electrochemical protective system of the water pipe was not connected to the oil product pipeline trass. Instead it was connected to protective system of the tank field. So, it was assumed that a difference in the electrochemical potentials of the two steel pipes caused the corrosion of the kerosene pipeline.

To verify this assumption, other parts of the sub-surface kerosene pipeline were put under investigation. Damages of the outside bitumen layer were also found at other locations. After removal of the bitumen layer at these parts of the pipeline no signs of outside corrosion were found. This verified the assumption that the two barriers system of protection against corrosion had worked under normal conditions but not in vicinity of the steel water pipe with a different electrochemical potential. As a result, it has to be assumed that the potential of the steel kerosene pipeline had become positive against the potential of the steel water pipe. As a consequence outside corrosion of the kerosene pipeline took place and resulted in the leakage. This could only happen because there was a damage of the outside bitumen layers of the kerosene pipeline and of the water pipe at locations very close to each other.

Because of the tiny hole in the steel pipeline (about 70 mm^2, Figure 3) caused by electrochemical corrosion, the low temperature and discontinuous kerosene transport processes the leakage was only detected after 4 weeks. Calculations of the leakage rates under pressure during the transport of kerosene to the tank field and under standstill conditions are shown in table 1. Unfortunately the pipeline was not blocked at times of stand still with the consequence that at these times there was a big contribution to the kerosene pollution of the soil.

Table 1: Calculation of the kerosene amount spilled into the soil

Period of time under transport pressure 152 h:	375 m³
Stand still with only hydrostatic pressure 448 h:	682 m³
Sum:	1057 m³ (846 t)

Figure 4: Water pipe (at the top of the picture) crossing the kerosene pipeline (copyright: operator)

ACTIONS TAKEN

As connection pipelines today have to fulfill the requirements of the regulation on installations handling substances hazardous to water and the safety operation regulation in Germany, the first action was to guarantee that the technical requirements are met. Today, double walled sub-surface pipelines are regarded as best available technique for transportation of fluids hazardous to water, but single walled pipelines enjoy preservation of the status quo if additional safety measures are applied. To guarantee the application of these contingency measures, the competent inspection authority (Regional Government Cologne) sent an ordinance with obligations that had to be met by the operator of the pipelines.

Before the re-use was allowed, a so called zero-measurement had to be carried out for all pipelines. For this a 100 % scrubbing of the pipelines for the determination of the wall thickness was necessary. At locations were scrubbing was not possible, contingency measurements had to be carried out to determine the wall thickness. The results from the scrubbing had to be used to calculate the life expectancy of the individual pipelines to guarantee a safe operation during the next ten years. This procedure has to be repeated every five years. Additional demands that were based on the German technical guidelines for sub-surface pipelines were :

- installation of a sophisticated leak detection device;
- yearly tightness tests;
- daily inspection of the pipelines corridor;
- lock of the pipelines at standstill times.

As the interference of the steel kerosene pipeline with the steel water pipe was main reason for the leakage, the operator changed the steel water pipe into a plastic pipe. To improve the cathodic corrosion, prevention the system was disconnected. The part in the vicinity of the tank field was connected to the electrochemical system of the tank field and electrically isolated from the other part of the pipelines corridor. In addition, the map containing all pipelines was reviewed to identify all pipeline crossings. An intensive measurement was carried out to identify all locations with disturbances of the electrochemical potential. At these locations the soil was removed and the bitumen coating renewed where necessary.

Meanwhile, the operator has decided to change to an above-surface pipeline connection between the production site and the tank field because the installation of a sophisticated leakage detection system is very laborious. A further advantage of this decision is that the pipelines corridor will be in compliance with the best available techniques in the future and the risk of further soil contaminations is considerably reduced.

LESSONS LEARNT

In an expert report on the damage evaluation, the following measures for the future handling of single walled underground steel pipelines were recommended:

- baseline measurements for the calculation of wall thickness reductions;
- involvement of the pipeline maintenance staff in building activities in the surrounding of pipelines;
- improvement of the leakage detection device;
- improvement of the cathodic corrosion protection device;
- faster remediation of detected deficiencies in the cathodic corrosion protection device.

Even if there are redundant protective measures against corrosion like bitumen coating and electrochemical protection, a leakage of a single walled pipeline cannot be excluded. Especially when there is other infrastructure equipment of the production site that is also electrochemically protected, differences in the electrostatic potential followed by increased corrosion can occur. The danger of interference with other equipment is even higher when part of the pipeline is located outside the production site and not all sub-surface building activities are identified by the operator.

Single walled sub-surface connection pipelines are no longer best available technology. The best option is to remove and substitute them by double walled or above ground pipelines with a second barrier against soil pollution but this is normally very expensive. For this reason single walled sub-surface connection pipelines enjoy preservation of the status quo when the integrity of the pipeline is guaranteed by contingency measures.

First, a so called zero-measurement has to be carried out that means a 100 % scrubbing for the determination of the wall thickness over the full length of the pipeline is necessary. At locations were scrubbing is not possible contingency measurements are necessary to determine the wall thickness. The results have to be compared with former measurements to calculate the corrosion rate and the life expectancy of the pipeline to guarantee a safe operation during the next ten years. This procedure has to be repeated every five years.

As already mentioned, the cathodic corrosion prevention system is sensitive against outside electrochemical interferences. To avoid this, maintenance staff has to know all the activities in and outside of the production site that can have an influence on the electrostatic potential of the pipeline. In addition, intensive measurements along the pipeline have to be carried out regularly to identify locations with interferences or damaged coatings. Needless to say that at these locations the necessary measures have to be taken.

The leakage detection device was only capable to notice leakage rates of at least 5 % of the maximum flow rate which means 5 m^3/h. As the leakage rate was lower than this because of the tiny hole the oil spill was not detected for a long time. In addition the pipeline was under hydrostatic pressure from the storage tanks during transportation breaks because the valves were open at those times. As a consequence kerosene also spilled into the soil during these breaks. To avoid this in the future the expert report on the accident gave the following advice. The leak detection device should be able to notice:

- 1 % of the maximum flow rate at times of transport;
- 10 - 50 l/h at times of stand still;
- Less than 5 l/h for creeping leakages.

The lock of the pipeline during times of stand still is an additional measure to reduce potential soil pollution.

Pressure and tightness tests on a yearly basis and additional tightness tests on a quarterly basis as demanded by the German technical guideline for subsurface pipelines as an alternative for a leakage detection system are not sufficient to avoid a massive leakage as is shown by this case. This is another lesson learnt form the accident. The German technical rules and standards only contain weak requirements concerning the operation prolongation of subsurface single walled steel pipelines transporting fluids hazardous to water. There are no requirements on the capability of leakage detection devices, and only a few control measurements are required for the assessment of the remaining lifetime. As a consequence the competent inspection authority has to induce the necessary control and maintenance measures by administrational order. This only works if the operator agrees or after an accident. For this reason, the revision of the concerned technical rules and standards was initiated.

Appendix

European scale
of industriels accidents

European scale of industrial accidents
Graphic presentation used in France

Further to difficulties which stemmed from the attribution of an overall index covering the consequences that are completely different according to the accidents, a new presentation of the European scale of industrial accidents with four indices was proposed. After having completed a large consultation of the various parties concerned in 2003, this proposal was retained by the Higher Council for Registered Installations. It includes the 18 parameters of the European scale in four uniform groups of effects or consequences:

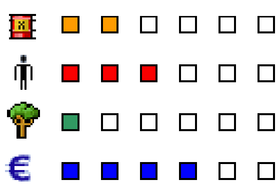
- 2 parameters concern the quantities of dangerous materials involved,
- 7 parameters bear on the human and social aspects,
- 5 concern the environmental consequences,
- 4 refer to the economical aspects.

This presentation modifies neither the parameters nor the rating rules of the European scale.

<u>The graphic charter:</u>

The graphic charter adopted for the presentation of the 4 indices is as follows:

When the indices are yet explained elsewhere in the text, a simplified presentation, without the wordings, can be used:



<u>The parameters of the European scale:</u>

Dangerous material released		1	2	3	4	5	6
Q1	Quantity Q of substance actually lost or released in relation to the « Seveso » threshold *	Q < 0,1 %	0,1 % ≤ Q < 1 %	1 % ≤ Q < 10 %	10 % ≤ Q < 100 %	De 1 à 10 fois le seuil	≥ 10 fois le seuil
Q2	Quantity Q of explosive substance having actually participated in the explosion (equivalent in TNT)	Q < 0,1 t	0,1 t ≤ Q < 1 t	1 t ≤ Q < 5 t	5 t ≤ Q < 50 t	50 t ≤ Q < 500 t	Q ≥ 500 t

* Use the higher "Seveso" thresholds. If more than one substance are involved, the higher level should be adopted.

Human and social consequences		1	2	3	4	5	6
H3	Total number of death: including - employees - external rescue personnel - persons from the public	- - - -	1 1 - -	2 – 5 2 – 5 1 -	6 – 19 6 – 19 2 – 5 1	20 – 49 20 – 49 6 – 19 2 – 5	≥ 50 ≥ 50 ≥ 20 ≥ 6
H4	Total number of injured with hospitalisation ≥ 24 h: including - employees - external rescue personnel - persons from the public	1 1 1 -	2 – 5 2 – 5 2 – 5 -	6 – 19 6 – 19 6 – 19 1 – 5	20 – 49 20 – 49 20 – 49 6 – 19	50 – 199 50 – 199 50 – 199 20 – 49	≥ 200 ≥ 200 ≥ 200 ≥ 50
H5	Total number of slightly injured cared for on site with hospitalisation < 24 h : including - employees - external rescue personnel - persons from the public	1 – 5 1 – 5 1 – 5 -	6 – 19 6 – 19 6 – 19 1 – 5	20 – 49 20 – 49 20 – 49 6 – 19	50 – 199 50 – 199 50 – 199 20 – 49	200 – 999 200 – 999 200 – 999 50 – 199	≥ 1000 ≥ 1000 ≥ 1000 ≥ 200
H6	Total number of homeless or unable to work (outbuildings and work tools damaged)	-	1 – 5	6 – 19	20 – 99	100 – 499	≥ 500
H7	Number N of residents evacuated or confined in their home > 2 hours x nbr of hours (persons x hours)	-	N < 500	500 ≤ N < 5 000	5 000 ≤ N < 50 000	50 000 ≤ N < 500 000	N ≥ 500 000
H8	Number N of persons without drinking water, electricity, gas, telephone, public transports > 2 hours x nbr of hours (persons x hours)	-	N < 1 000	1 000 ≤ N < 10 000	10 000 ≤ N < 100 000	100 000 ≤ N < 1 million	N ≥ 1 million
H9	Number N of persons having undergone extended medical supervision (≥ 3 months after the accident)	-	N < 10	10 ≤ N < 50	50 ≤ N < 200	200 ≤ N < 1 000	N ≥ 1 000

Environmental consequences		1	2	3	4	5	6
Env10	Quantity of wild animals killed, injured or rendered unfit for human consumption (t)	Q < 0,1	0,1 ≤ Q < 1	1 ≤ Q < 10	10 ≤ Q < 50	50 ≤ Q < 200	Q ≥ 200
Env11	Proportion P of rare or protected animal or vegetal species destroyed (or eliminated by biotope damage) in the zone of the accident	P < 0,1 %	0,1% ≤ P < 0,5%	0,5 % ≤ P < 2 %	2 % ≤ P < 10 %	10 % ≤ P < 50 %	P ≥ 50 %
Env12	Volume V of water polluted (in m^3) *	V < 1000	1000 ≤ V < 10 000	10 000 ≤ V < 0.1	0.1 Million ≤ V< 1 Million	1 Million ≤ V< 10 Million	V ≥ 10 Million
Env13	Surface area S of soil or underground water surface requiring cleaning or specific decontamination (in ha)	0,1 ≤ S < 0,5	0,5 ≤ S < 2	2 ≤ S < 10	10 ≤ S < 50	50 ≤ S < 200	S ≥ 200
Env14	Length L of water channel requiring cleaning or specific decontamination (in km)	0,1≤ L < 0,5	0,5 ≤ L< 2	2 ≤ L< 10	10 ≤ L < 50	50 ≤ L< 200	L ≥ 200

* The volume is determined with the expression Q/C_{lim} where:

- ✓ Q is the quantity of substance released,
- ✓ C_{lim} is the maximal admissible concentration in the milieu concerned fixed by the European directives in effect.

Economic consequences		1	2	3	4	5	6
€15	Property damage in the establishment (C expressed in millions of € - Reference 93)	0,1 ≤ C < 0,5	0,5 ≤ C < 2	2 ≤ C< 10	10 ≤ C< 50	50 ≤ C < 200	C ≥ 200
€16	The establishment 's production losses (C expressed in millions of € - Reference 93)	0,1 ≤ C < 0,5	0,5 ≤ C < 2	2 ≤ C< 10	10 ≤ C< 50	50 ≤ C < 200	C ≥ 200
€17	Property damage or production losses outside the establishment (C expressed in millions of € - Reference 93)	-	0,05 < C < 0,1	0,1 ≤ C < 0,5	0,5 ≤ C < 2	2 ≤ C < 10	C ≥ 10
€18	Cost of cleaning, decontamination, rehabilitation of the environment (C expressed in millions of € - Reference 93)	0,01 ≤ C < 0,05	0,05 ≤ C < 0,2	0,2 ≤ C < 1	1 ≤ C < 5	5 ≤ C < 20	C ≥ 20