LESSONS LEARNT from INDUSTRIAL ACCIDENTS

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31 May and 1 June 2017 – Lyon

European Union Network for the Implementation and Enforcement of Environmental Law

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RÉPUBLIQUE FRANÇAISE

Ministère de l'Environnement, de l'Énergie et de la Mer

Ministry of the Environment, Energy and the Sea

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Enrich the debate

The European Union Network for the **IMP**lementation and Enforcement of **E**nvironmental **L**aw (commonly known as the IMPEL network) was created in 1992 to promote the exchange of information and experience between the environmental authorities. Its purpose is to help building a more consistent approach regarding the implementation and enforcement of environmental legislation.

Since 1999, this network has been supporting the French project on lessons learnt from industrial accidents. In order to promote the exchanges, which are crucial for the improvement of the prevention of industrial accidents and the control of risks management, France regularly organizes a seminar for European inspectors, where about sixteen recent accidents are presented. The analysis of disruption factors and root causes, known or supposed, is rigorous and distinguishes technical, human and organizational levels.

The active participation of inspectors from numerous European states enables to cross views and to enliven the debate, which explains the success of these seminars.

Reports of all the events presented since 1999 are available on the Barpi website :

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LESSONS LEARNT

from industrial accidents

IMPEL Seminar

Lyon, 31 May and 1 June 2017

Table of contents

Effectively evaluating risks under degraded operating conditions

A degraded situation is merely an initial phase that could lead to an accident with serious consequences.

"Operating in a degraded mode" refers to a condition during which operations are ongoing despite there being no access to all necessary or normally expected functional resources upon completion of the corresponding risk analysis, whether such resources are organisational or technical.

It is essential for a facility operator to identify "deviations" that serve to degrade a situation in order to respond, by means of a well-informed risk analysis, in a way that makes it possible to implement appropriate compensatory measures.

In some cases however, this deviation becomes "acceptable" for the operator or for the various actors, who exhibit what experts in technological risks call the normalisation of deviation, which means accepting a relatively severe risk that is perceived to be highly unlikely to occur when compared with the immediate benefits of this normalisation (e.g. smaller investments in safety, less disturbance to production schedules, no time lost treating this risk).

Below are the main lessons learnt in pursuit of effectively evaluating risks under degraded operating conditions.

1. Never ignore or overlook the deviation

Many examples show that poor communication among actors, ambiguous instructions, the assignment of multiple tasks, a lack of controls or inability to treat deviations expeditiously can all lead to omitting a deviation either voluntarily or involuntarily.

- ARIA 42163: Around 10:30 pm at a Seveso-rated chemical plant, a sensor detected a rapid rise in conductivity inside a heat exchanger. Upon tripping the sensor alarm (at a 50 µS level), the automated safety controller isolated the circuit. A 2nd conductivity-meter, which had been idled and scheduled for replacement by the maintenance unit, showed a value of 0 µS. Not informed that this device was inoperable, technicians proceeded with sampling to remove any doubt and notified the duty manager, who analysed the situation, did not wait for the laboratory results, bypassed the conductivity-meter whose alarm had triggered, and restarted manufacturing. Ultimately, only a limited discharge of phosgene into the environment was observed, thanks to an effective 2nd safety barrier.

ARIA 42163 © Site Operator

- ARIA 14693: Mix of incompatible products during a transfer operation due to the fact that the technician had not been informed of a change in chemical product, resulting in 3 injuries.
- ARIA 13917: Overflow of a tank and pollution entering a river subsequent to the launch of a fuel oil transfer operation between 2 tanks by a technician who had left his station in forgetting about the ongoing transfer.
- ARIA 30486: A 60 m^3 leak of orthoxylene into the OISE River caused by neglecting to replace the buffer on an inspection flange.

2. Avoid normalising the deviation

Normalising the deviation entails considering that the degraded situation, which in theory should be treated as exceptional, becomes normal out of short-sightedness. The multitude of reasons for this tendency are often correlated with burdensome constraints, like maintaining production levels, avoiding heavy capital expenditures, etc.

The most infamous accident is undoubtedly Bhopal (ARIA 7022) with at least 3,780 fatalities. Operators incurring debt at a site were interested in saving money: refrigeration down for several months at a time; defective temperature, pressure and level indicators in the tank; inoperable gas washer; idled flare; no more inerted storage; etc.

The installation of permanent shunts is a frequent cause of accidents stemming from normalised deviations.

A deep-rooted cause of this normalisation process is related to ergonomics (e.g. constraints generated by repeated alarm activation, poorly designed tanks):

- ARIA 17531: High level and very high level alarms bypassed on gasoline tanks. Consequence: overflow into the retention basins.
- ARIA 38674: Delayed operations upon restarting a fungicide production unit in order to avoid reliance on 2 successive work shifts. Consequence: explosion in the spray tower.
- ARIA 49246: Bypassing a security feature that normally requires technicians to remain during a transfer operation. Consequence: fuel spill.

Another situation often encountered when the initial deviation is "normalised" consists of introducing a second deviation, which then offers a streamlined solution when coping with a degraded situation:

- ARIA 47892: Installation of a shunt in order to maintain a float in the upper position given that it was defective and responsible for untimely and frequent outages. Consequence: fire outbreak quickly brought under control.

3. Do not neglect warnings or public and media sensitivity

As a situation worsens and becomes more seriously degraded, the operator might hope to control the situation, in addition to being tempted to avoid spreading panic in the neighbourhood or disturbing the authorities.

In the case of accidents involving rapid kinetic reactions, it is essential to quickly inform authorities so as to provide them with the maximum amount of time to protect the local population.

Some accidents reveal that the operator's decision not to comply with this principle (ARIA 47277) caused a tremendous ethylene cloud (100 m long by 4 m high) to be released from a chemical site. The smallest spark would have unleashed a UVCE (Unconfined Vapour Cloud Explosion) event. Despite the presence of this hazard, the operator still decided not to activate the Internal Emergency Plan and authorities were not notified until 2 days after.

In the case of degraded operations with slower kinetics (ARIA 48764, 48766), neighbours may feel anxious about the situation, especially when nuisances are readily perceptible outdoors (odours, smoke, noise). The operator must not overlook the benefit of real-time communication regarding these events in order to explain the type of deviations involved and thereby reassure the local population (ARIA 43616).

For public authorities, the primary difficulty raised is the decision to be made in the aim of protecting both the population and the environment. The balancing act required is based on the risk of accident occurrence and its consequences, plus the unintended consequences of measures adopted (e.g. evacuation, confinement, road closures).

As an example, in February 2017, American authorities were fearing collapse of the backup spillway at the Oroville Dam. They requested 200,000 residents evacuate the affected zone. Three days later, following a sizeable drop in the dam water level, the population evacuation order was transformed into a simple alert.

This recent positive example (ARIA 49207) demonstrates that potential consequences in the event of a dam break received greater consideration than the logistics difficulties inherent in any such decision.

4. Areas for improvement

The aforementioned event analysis reveals that lines of organisational defence serve to guarantee control over maximum risks, even under degraded conditions. This defence entails at least the following:

- identifying the deviations from normal operations;
- tracking these deviations and conducting regular reviews to monitor their resolution and/or the effectiveness of compensatory measures;
- performing an in-depth risk analysis that takes into account this unique set of operating conditions by determining not only the stable process phases, but also the means by which a degraded state arises. Such an analysis constitutes a key element in accidental mechanisms featuring rapid kinetics, which leave little margin to react if the degraded situation has not been properly examined ahead of time;
- anticipating deviations by introducing response guidelines, i.e. procedures describing how to return to a normal situation and the relevant set of compensatory measures devised in a stress-free setting;
- addressing operational anomalies, like deficient emergency response resources (electric generating set, inverter, cooling, fire protection, etc.);
- assessing degraded situations from the perspective of worst-case consequences and not best-case consequences, then programming the alarm on this basis, even if in the end the major accident could be averted;
- reworking the risk/benefit calculation, which may lead to refusing expenditures in order to avoid a risk that seems highly unlikely or even acceptable;
- resisting the temptation to minimize the seriousness of an unlikely hazard when coping with multiple productivity constraints;
- tuning in to weak signs: personnel warnings, drift in production indicators, increased rate of equipment down time;
- communicating in real time on events, for the purpose of reassuring the local population.

A critical and attentive approach to safety in day-to-day activities, along with calculation of the risk/benefit objective and an awareness of weak signs, constitutes a state of mind to be displayed by senior management. This mindset must be nurtured day in day out to allow the safety “pointer” to indicate the appropriate direction among the various activity constraints.

Water / molten metal explosion in a foundry

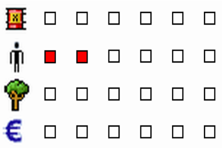
21 January 2015

Feurs (Loire)

France

Explosion
Water / molten metal
Metallurgy
Control

THE ACCIDENT AND ITS CONSEQUENCES



This industrial site, in operation since 1915, comprises a steel foundry.

The business employs a workforce of some 300 persons and is specialised in manufacturing moulded steel components intended for the rail industry, nuclear applications, armament, farm machinery and public works. The industrial zone surrounding this site features: railway line running along the site boundary, industrial buildings, residential dwellings just 100 m from the site, and the water table situated at a depth of between 1 and 3 m.

The foundry activity entails the use of two “arc” melting furnaces (furnaces 3 and 4), offering a melting capacity of 7 t each, bringing the total annual maximum production of the foundry to 50,000 t.

THE ORIGIN AND CAUSES OF THIS ACCIDENT

Origin

The source of this accident was the contact initiated between molten metal and water or humidity that had accumulated at the bottom of casting pit 4. During the process of pouring metal into the foundry ladle, some 400 kg of molten metal accidentally fell into the pit. The abnormal presence of water at the pit bottom triggered both an explosion, in the form of a dry expansion (yet without spraying any metal), and the release of a large plume of dust. The blast resulting from the explosion, funnelled by the pit walls, damaged the roof made of asbestos cement sheets, which acted like a fuse vent (many sheets landed on the floor or were displaced). No other structural damage to the building was observed.

The accident occurred around 5:20 am. First responders were called by the foundry operator at 5:28, when the 76 plant personnel present at the time were evacuated. Casualties amounted to 8 minor injuries, 3 of whom were transported to the nearby hospital while the other 5 were treated on-site.

Furnace No. 4, © Site operator

Causes

The proven or suspected causes cited were as follows:

- Defective pit drainage:
  - the bottom level of the casting pits was positioned at 3.8 m (pit 4) and 3.50 m (pit 3) below ground;
  - since the ground was permeable, the water table level when the accident struck was recorded at -1.2 m, which was significantly higher than the pit bottom levels;
  - after a fatal accident under the same set of circumstances at a neighbouring site in 2011, this operator commissioned an appraisal in 2012 to assess the pits lying beneath the melting furnaces in order to verify their impermeability and determine how best to cope with potential water infiltration;
  - that assessment did not reveal any major structural disorders yet did report a highly deteriorated concrete surface condition, together with signs of water infiltration (traces of humidity and the presence of water) on the rear faces of both pits. The infiltration was apparently due to the structures (pits) being submerged in groundwater. Subsequent to this assessment, works were engaged to drain the pit walls;
  - Expert appraisals of the furnace 4 pit, following the accident on Wednesday 21 January 2015, revealed the absence of a drainage film on at least one of the pit walls.

- Lack of controls, or even appropriate guidelines, to ensure no water accumulation in the pit bottom:
  - during the Hygiene and Safety Committee session held after the accident, it was mentioned in front of the environmental inspectors that management had on several occasions been notified of the presence of water at the pit bottom (e.g. humidity in the large pit was written in the 1 December 2014 safety log entry);
  - the Head of Maintenance indicated that preventive maintenance was being performed, along with a visual inspection of the furnace every Monday morning, to confirm the installation was not leaking water;

- no detection of humidity at the pit bottom was posted to the safety log entry on the day of the accident (Wednesday);
- the procedures and data recordings transmitted attest to the fact that a “1st level” control protocol applied prior to starting up an arc furnace had indeed been in place;
- preventive maintenance steps on idle or operating furnaces, in addition to targeted controls at different intervals (weekly, monthly, semi-annually and yearly), were being conducted;
- it should also be noted that the water levels in the various sumps were not being monitored as part of any special procedure.

ACTIONS TAKEN

26 January 2015: Prescription requiring adoption of emergency measures issued to the operator, who had been informed as of 21 January, concerning the following:

- immediate suspension of melting activities for furnaces 3 and 4;
- implementation of conservation-oriented measures (securing the facility and banning access to the site);
- request for submission of an accident report within 2 weeks;
- additional details on the conditions for resuming melting activities.

3 February 2015: Submission of the accident report presenting the origin and causes of the incident, expert appraisals and ongoing investigations, as well as solutions proposed for securing the furnace 3 pit, while awaiting the completion of works on the furnace 4 pit, which had sustained damage from the explosion.

March through May 2015: Communication of the following:

- the various scenarios involving potential deficiencies, coupled with their associated level of likelihood and seriousness scores for furnaces 3 and 4;
- technical memoranda describing each risk management measure (RMM);
- set of revised safety procedures in light of these installation modifications.

The entire array of proposed active and passive technical systems brought the final risk level to 10^{-8}. The various RMM dedicated to works and machinery were introduced in order to prevent any recurrence of such an accident (double casing, moisture meters, level probes in the sumps, etc.).

Authorisation to resume the activity of furnaces 3 and 4 was granted on 24 March and 25 September, respectively.

Under these conditions, the operator was asked to update the site safety report by taking into account the risk of a rising water table during flood events, plus all other possible water sources (impermeable roofs, water circuits running in the vicinity, cooling water storage pits, etc.).

28 September 2015: Administrative order requesting additional prescriptions to specify the RMM for furnaces 3 and 4, including three RMM rated at a “2nd level” of confidence and three others rated with a confidence of “1”. Also requested was submited of a set of written procedures establishing: safety instrument control frequencies, data recording protocols, and corrective actions in case of operational malfunction.

This accident gave rise to six on-site inspections, in addition to many meetings held during 2015.

LESSONS LEARNT

Despite a similar accident occurring at an adjacent site in 2011 and awareness of the presence of a water/molten metal risk, the experience feedback still pointed to a lack of appropriate resources.

The long-standing location of a foundry within a hostile environment (water table near ground level) led to a number of serious operating constraints, requiring:

- substantial financial outlays for maintaining both the building structure and industrial machinery;
- adaptation of measures and resources to better meet the site's physical and technical constraints;
- the involvement, discipline and vigilance of all members of personnel day in day out.

The measures adopted still raised some technical issues, including:

- sumps located near melting furnaces, creating a configuration that raises the water table.
- relevance of drainage systems on installations featuring in such a high risk of accident occurrence.

With the infiltration risk being known, the resources allocated on both the technical and organisational sides, along with attention paid to weak signals (e.g. alarms activated by the personnel), would serve to avoid this type of accident, for which the consequences could have been much worse.

Leak of pressurised flammable gas within a petrochemical complex

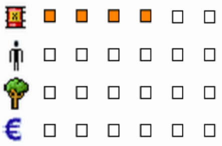
17 October 2015

Gonfreville-l'Orcher (Seine-Maritime)

France

Leaks
Liquefied gas
Petrochemicals
Subcontracting
Guidelines

THE ACCIDENT AND ITS CONSEQUENCES



At a petrochemical facility, a liquefied flammable gas began leaking on Saturday 17 October 2015 at 5:33 pm. The incident lasted 21 minutes. The source of the leak was located in a zone containing three compressors ("ethylene" compressors 1 and 2, operating in an alternating mode, with just one compressor running at the time of the accident, namely "flare gas" compressor 3). The 7 gas detectors present in the zone were saturated at 100% of the lower flammable limit. The alarms on these detectors were automatically relayed to two control rooms as well as to the main fire response station. A loud noise could be heard both on the site and in the control rooms. A gas cloud, perceptible in the form of a fog bank approximately 4 m high by 100 m long, was also observed. The upper vibration threshold on compressor 1 was reached, causing two seconds later the shutdown of the compressor motor and closure of its discharge valve. Breaching the second gas detector threshold caused the motor on the third compressor to switch off and the closure of both its suction and discharge valves. Only the suction valve on compressor 1 remained open.

Within the first few minutes, teams suspected a problem had occurred on compressor 3. Technicians from the 2 control rooms involved left their workstations to perform field reconnaissance. Only after seven minutes, was it determined that the problem had in fact arisen from compressor 1.

The facility operator's response resources were deployed on-site. More specifically, a vehicle equipped with a fire hose was able to protect, by means of a water curtain, the furnaces at an adjacent unit. Other resources were placed to create water curtains that would contain the gas cloud. The personnel in neighbouring units were requested to seek shelter.

The seriousness of the event was reassessed 11 minutes after the outbreak. The on-call team was notified at this point.

Two technicians wearing additional individual protective gear, to muffle the extremely loud noises, engaged in corrective actions by handling two valves located a few metres upstream of the compressor zone. This operation took place 21 minutes after the onset of the leak, stopping it nearly instantaneously. The cloud dissipated right away. The suction valve on compressor 1 then became accessible and could be closed by the technician.

No fire nor explosion ensued, and no injuries were reported. Also, no installations sustained damage outside of compressor 1 (with damage limited to ejection of the hatch).

The internal emergency plan was not activated. Authorities were not notified on the same day by the operator, except for the port watchman. The inspection of classified facilities service was informed of the incident the following Monday.

THE ORIGIN AND CAUSES OF THIS ACCIDENT

© Site operator

This leak was caused by ejection of the hatch on one of the check valves fitted onto compressor 1. This valve was found lying 6 metres from the compressor.

Expertise pointed a poor clamping of the studs, exacerbated by the beating of the valve joint given that this joint had not been annealed at the time of assembly, in violation of procedure. This condition, combined with a damping error of the dowel already close to the plastic deformation, caused a beating of the check valve-lamp-lid stacking sequence, plus the failure of a stud and ejection of the stack. The compressor showed no signs of operating anomalies prior to this incident.

The duration of the leak (21 minutes) was particularly wide to the following causes:

- unfamiliarity with the automation in connection with the compressor motor stop in case of trigger by the high threshold of vibration. The operators did not know that the valve of the compressor did not automatically close in this particular case and that it was therefore necessary to order this closure remotely from the control room by actuating the emergency stop button;
- operators from the control room gave priority to field intervention. As a result, the information arriving in the control room could not be integrated, as no operator remained in the control room concerned.

ACTIONS TAKEN

The first site visit by the inspectors of classified facilities cited two instances of egregious regulatory non-compliance (namely the regulation requiring all equipment be secured subsequent to gas detection, and the ban on vehicle traffic at the facility once a gas alarm has been activated), along with 11 observations focusing on:

- verification of the compliance with company requirements for all services of subcontractors involved in compressor maintenance;
- organisational improvements allowing for the permanent presence of a control room technician capable of responding appropriately to relayed alarms;
- the need to conduct an analysis of all compressors;
- update of safety reports to incorporate the risk analysis of the site's compressors, and identification of both the existing and additional safety features to be implemented;
- the necessity of activating an internal emergency plan under such conditions, with the triggering of a general siren for the whole plant and interruption of traffic and all hot spot work;
- the need to deploy resources that block vehicle access to the zone where the incident has occurred;
- awareness of the risk giving rise to fire-fighter vehicle response within the zone of the incident outbreak (exacerbation by a hot spot);
- the need to remind technicians of the emergency stop function when securing a compressor;
- the need to regularly train personnel through role-play drills of incident situations;
- study of the domino effects had the leak ignited;
- submittal of a thorough incident report.

The compressor was completely refurbished by replacing all the studs (all check valves) and reassembling the fastenings on all main linings, plus the cylinder spacer, housing spacer and brackets. The unit was placed back into service on 23 December 2015. The revised maintenance task list was shared with the subcontractor assigned to maintain the compressor. A review and update of task lists on the other compressors at the facility were also undertaken. During the month following the incident, the connection of both the isolation actuation and the automatic compressor security actuation upon gas detection were performed. A reminder to teams was issued pertaining to the functionality of systems in place for securing the compressors.

Organisational modifications were introduced as well. Once the second threshold was breached on two gas detectors, the internal emergency operations plan would now be activated, which would impose triggering the site's general alarm, thus prompting the suspension of all traffic on the site. As another direct consequence, the authorities would be informed. On the whole, the criteria for activating the internal emergency plan would be simplified.

A second inspection was conducted in order to monitor the set of requested improvements. The prescriptions listed in the applicable Prefect order were then strengthened in various ways, namely:

- permanent presence of a control room technician;
- modifications to the overall expectations of gas detectors (especially with the introduction of objectives for testability, compensatory measurements in the event of malfunction, etc.);
- specifications of actions to be taken in the event gas detection thresholds were breached;
- clarification of the objective regarding regular personnel training;
- addendum whereby these personnel drills must entail simulated incidents involving zones being managed by distinct teams;
- for compressors capable of causing hazardous phenomena with consequences extending beyond the site boundary, the emergency stop buttons must allow for complete site safety.

An unexpected internal emergency drill was also organized in order to verify that these provisions were indeed being respected.

LESSONS LEARNT

Although this incident was not responsible for any consequences outside the site, nonetheless it is still important to communicate with authorities. The town mayor expressed regret for not having been informed of this event by the site operator. By activating the internal emergency plan, this level of communication would have been better managed.

The incident occurred on a Saturday afternoon, meaning that the site was experiencing relatively little activity and vehicle traffic. At another time of the week, the cloud might have encountered a hot spot due, for example, to automobile traffic in the zone, in which case it could have ignited causing damage to the site as well as effects beyond the site boundary (between 20 and 50 mbar in the event of a UVCE type explosion). It is thus essential for technicians to be able to react very quickly using efficient means to stop the leak and prevent contributions from hot spots within the given zone.

FACT SHEET

Anticipating emergency response difficulties

The handling of an industrial accident is often rife with obstacles, e.g. water supply constraints, inappropriate response protocol in light of product properties, inefficient information provided by bystanders, and undervaluation of the risk of loss. 6.5% of all accidents recorded at France's classified sites have experienced major difficulties during emergency responses. The sectors of activity most heavily affected are waste management (16% of all cases) and farming (14%). These installations exhibit a different configuration than those found in more highly technical sectors, like chemistry (6%), which adopt a more formal approach when preparing to cope with accidents and implement emergency plans (both internally and externally). Wholesaling activities (8%), including cereal silos, and warehousing (5%) are other activity categories that raise concerns during emergency situations.


ARIA 39164 © Haut-Rhin Fire Services

This fact sheet offers a sampling of the errors to avoid and serves to better anticipate response difficulties, by drawing from an analysis of 395 events post-2010.

1. Facilitating access to the site and hazardous zones

1.1. Gaining access to the facility even during periods of closure

Fire-fighters are often called to respond at unoccupied industrial sites (nighttime, weekends, etc.). They must therefore force open gates, use extrication tools, etc. The waste sector, while not alone, is frequently involved in such calls. Sites that are definitively closed also present problems *(ARIA 44917: On the premises of a company out of business, fire-fighters are blocked by boulders sealing the entrance).*

While taking into account the various safety requirements, a facility operator must ensure accessibility to emergency crews during his absence *(ARIA 42875 : After a fire, the site operator installs a system to close the gate with a chain and combination padlock, in addition to use of a call center).*

1.2. Incorporating response into the site and facility design

The damage caused by the accident itself or even the composition of on-site products may impede access (*ARIA 45977 : Structural instability and risk of collapse ; ARIA 46459 : Closure of the valves on an oxygen tank damaged by heat fluxes rendered impossible ; ARIA 42570 : The presence of corrosive products hinders response ; ARIA 47324 : At a waste treatment site, access constraints to a fire source located beneath a molten metal layer)*.


ARIA 41921 © DPA

Installation design may interfere with a successful response protocol, to the same extent as operating conditions *(ARIA 45578 : Difficulties experienced when extinguishing a fire on premises solely accessible via a hatch ; ARIA 45508, 48298 : Poor access to the street network, site clutter).*

It is therefore essential to take into account, from a “practical” perspective, the set of requirements leading to a quick response when designing facilities and installations, and then continue respecting these requirements on a daily basis during site operations.

2. Awareness among actors of the risks incurred

2.1. Understanding the potential hazards and accident scenarios


ARIA 45565 © AFP

Many mishaps during emergency responses are caused by a lack of knowledge of both risks and product dangers *(ARIA 43846 : During a fire outbreak at an ammonium nitrate plant, fire-fighters focusing on the toxic NH_3 risk failed to account for the explosion risk. The collapsed structural frame caused a detonation killing 15 people ; ARIA 46803 : In response to fire at a chemical products warehouse, fire-fighters resort to a water attack despite the presence of sodium cyanide, which reacts violently in contact with water. Two devastating explosions follow, resulting in 173 victims).*

In some instances, information is available but not adequately taken into consideration (*ARIA 42817: During an exothermic polymerisation reaction, in not heeding the site operator's warning, fire-fighters elected to use water cannons. The subsequent BLEVE caused 37 deaths).*

To ensure an efficient emergency response, in-depth knowledge of product dangers and accident scenarios is required, and such knowledge must be shared by the facility operator, on-site staff and first responders. This protocol means that technical and organisational measures are adopted ahead of time in order to avoid exacerbating the consequences of an accident. The allocation and preparation of response resources and crew protective gear, given the potential for working in hostile environments, then becomes more streamlined (*Dense smoke ARIA 37931 ; Risk of explosion ARIA 42917 ; Threat from projectiles ARIA 48421 ; Toxic atmosphere ARIA 38795, 38450 ; Radioactive risk ARIA 47678 ; Electrical risk ARIA 43023 ; Swampy terrain ARIA 40580).*

2.2. Training personnel to ensure a top-quality response

Employees' familiarity with the emergency response protocol is imperative. A well-executed internal response often slows propagation of the incident and may avoid the need to call for external backup. Conducting regular drills promotes optimal reactions when an accident strikes. In contrast, poorly prepared employees could hinder a response *(ARIA 48660: Failure to close a valve unfamiliar to site staff leads to the discharge of fire extinction water into a river).*

2.3. Coordinating early on with emergency responders

ARIA 41638 © Le Dauphiné

Even in the absence of emergency plans (internal, external, site-specific plans), emergency situations must be anticipated between operator and fire-fighters. Adopting protocols, implementing appropriate fire-fighting resources and safety devices, and prioritising techniques is decisive. The joint establishment of response procedures and execution of joint drills help avoid hesitation and coordination problems *(ARIA 46675: Misunderstandings between site operator and fire-fighters lead to lithium pollution via a confinement valve that had remained open)*.

The operator must also incorporate recommendations issued by emergency response services regarding the configuration of installations, e.g. compartmentalisation. The same applies to designing fire-fighting resources like detection, smoke removal, water supply sources (*ARIA 45508: Water supply constraints without a proper reserve, as specified in the Prefect's order).*

3. Relying on additional expert input as needed

During responses complicated by the configuration of installations or substances involved, the reliance on specific expertise may be beneficial in determining the right course and decisions. It could be include the GRIMP (recognition and intervention group in perilous environments) or the emergency situations support unit (or CASU) sponsored by the INERIS Institute, or an expert specialised in the given activity. Such is often the case with silos (*ARIA 42815: 5 days of planning are necessary to fully control a situation following a malt silo explosion).*

Interprofessional solidarity networks like USINAID for coping with chemical industry accidents, set up by the UIC trade organisation (French federation of chemical industries), or their foreign counterparts might also be viewed as a resource *(ARIA 43772: Implementation of the Belintra protocol after the explosion of a railcar containing acrylonitrile at the Belgian border).*

4. Safeguarding against inappropriate public reaction to an announcement

The behaviour of local residents or the general public could interfere with an emergency response, thereby exacerbating the consequences of an accident or triggering a subsequent accident *(ARIA 42653: Motorists damage fire-fighters' hoses; ARIA 40903: Explosion caused by the cigarette of someone in a crowd that had congregated around an oil pipeline leak results in 120 deaths in Kenya).*

It is key to anticipate, as best as possible, the concern shown by locals. Communicating with the public, like with neighbouring industries, is fundamental both before and during an event (real-time communication) in order to inform, explain and reassure.

ARIA 40903 © Capital FM

5. Coping with the unforeseeable

Despite the best efforts at anticipation, some uncontrollable elements still influence how response is handled. Weather conditions top the list in terms of exerting a major impact *(ARIA 41638: Frozen water in fire hoses and an intense cold snap prevent valves from working)*. These unforeseeable circumstances must, to the greatest extent possible, be acknowledged when defining response strategies and, subsequently, in the field by relaying accurate and timely information.

Nickel sulphate discharge into a river
July 2014
Harjavalta
Finland

Pollution
Environmental impact
Communication/information/crisis
Maintenance/work/repairs
Periodic control

THE ACCIDENT AND ITS CONSEQUENCES

In southwest Finland, 66,000 kg of nickel, in the form of nickel sulphate solution, are discharged into the river Kokemäki on the 5 and 6 July 2014.

The facility at the origin of the discharge is based in the city of Harjavalta and is part of an industrial platform specialised in non-ferrous-metals (copper and nickel). The facility produces about 50,000 t of nickel cathodes, briquettes and chemicals per year. It produces metallic nickel used as raw material in manufacturing of stainless steel and various metal alloys used for surface treatment purposes. The process is composed of several hydrometallurgical subprocesses. The production line processes raw nickel, nickel sediments and some secondary raw materials. After grinding, leaching and solution purification phases, the process solution is divided and directed into cathode and briquette production lines. The facility also produces nickel chemicals (inorganic nickel salts) from the nickel sulphate solution.

The facility is submitted to both Seveso and IED directives. The industrial platform is situated within a groundwater catchment area (1st class in Finnish classification). The groundwater and the surface are historically deeply contaminated with heavy metals due to a long time industrial activity on the area. The facility's wastewater, after passing through a treatment plant, and the cooling water are rejected to the Kokemäki river. This river is one of the biggest in Finland with an average flow rate of 238 m^3/s. The nearest dam is located directly downstream of the industrial area.


Dead mussels © Southwest Finland ELY-center

The accidental nickel discharge lasts during 30 hours. The highest measured nickel concentration in the river water is 8,700 µg/l (knowing that the environmental quality standard for instant value is 34 µg/l and that the normal concentration in the river is 1 µg/l). Smaller amounts of heavy metals, such as cobolt (1,265 kg) are identified.

Less than one week after the discharge, environmental consequences are observed : millions of dead mussels are floating in the river. One of the four mussel species damaged is the "thick-shelled river mussel", *Unio crassus*, specie protected by the European Habitats directive. According to investigations, up to 1,1 million Unio crassus specimen died, i.e. 15 % of the population. Total mussel deaths amounts to about 100,000 kg in biomass. The environmental consequences affected the river on a length of a 35 km, nearly until the point where it flows into the sea.

Regional environmental authorities in charge of the supervision of the facility (Southwest Finland ELY-center) obtain the information about a discharge on Monday 7 July, one day after the plant stopped the leak. The magnitude of the discharge is initially largely unknown. This lack of information causes delays in the decision process within the environmental authority (nature of the measures to be taken to perform samples, measures, to inform people…). The actual magnitude of the discharge is revealed by the press the next day.

At the end of the week, when the massive mussel deaths are discovered, media puts a lot of pressure on the authorities and urges them for action. The accident becomes national focus and a major discussion topic. Indeed, the summer's biggest political event and a big music festival take place in the city of Pori, situated 30 km away from Harjavalta, along the same river. The media reveals that there are diverging opinions between the different authorities and experts regarding the precautions to be taken with the use of the river's water and fish. Authorities are blamed for not reporting soon enough and not warning about the consequences. Social media plays a large role in the diffusion of information and rumours. The authority was unable to answer all the questions raised by the citizens.

After a few days, the cooperation between the different authorities gets organised. Daily meetings are conducted between the Regional environmental authority, public health authorities and fishery authorities. National level environmental experts from the Finnish environmental institute, universities and ministries take part in the discussion and decision process. The media pressure reduces.

THE ORIGIN AND THE CAUSES

The accidental discharge happened after a maintenance operation at the solution purification part of the facility. An incorrectly assembled heat exchanger triggered a leakage in the cooling system. Usually, such a leakage is quickly detected thanks to the monitoring system. But this time, because of several human errors, it took 30 hours to identify and fix the problem.

Indeed, at the time of the accident, several measurement instruments were out of order. Other automatic measurement instruments (pH, conductivity) were working but the employees did not control the results. Some daily samples, to be performed in the outgoing cooling water, were not conducted. The technical problem was detected in another part of the plant : a very high nickel concentration was observed in the outgoing cooling water. This anomaly was first wrongly interpreted as a leakage from another part of the facility. In reality, it was caused by the very high nickel concentration present in the incoming cooling water taken in the polluted Kokemäki river.

Most of the facility's cooling systems use secondary cycles or other closed systems. But, on the opposite, the process part in question has an open system with simple plate heat exchanger. The risks were supposed to be minimised through the monitoring system in place. Such a configuration had therefore been authorised by the environmental permit authority several year before. In this case, the monitoring system did not play its role.

FOLLOW-UP ACTION TAKEN

The accident took place during the summer period. The environmental authority had to adapt its working methods to deal with the case. After a few days of set up, the system was operational:

- some holidays were interrupted to get the best experts available;
- daily meetings using video-conference systems were initiated to get the best expertise at national level (Finnish environmental institute). Video-conferences were also used to share information with local authorities and with public health authorities;
- daily and then weekly press releases were published to provide answers to media and citizens.

Regular sampling in the river water to control the pollution level started about 24 hours after the accident and lasted during two years. Mussel deaths were investigated by diving. Modelling was used to estimate dispersion to the sea and to replace missing samples from the first days of the discharge. Sediment, vegetation and fish impacts were measured. The facility owner is responsible for the financing of the investigations. All these investigations are conducted according to the environmental authority's instructions and decisions.

Investigations in the river © Southwest Finland ELY-center

Because of the Habitats directive species involved and the large-scale mussel deaths, the environmental liability directive is applied to remedy the damages to protected species and the ecosystem. The facility owner will also be liable for paying all the remediation measures.

The police has investigated the case from the very beginning. The prosecuting authority is examining whether to file charges for environmental offence against the company or its employees.

LESSONS LEARNT

The accident reveals that authorities must be prepared for reacting fast to unexpected crises. The environmental authority identified ways of progress to react quicker in case of a new similar situation. The environmental authority has to be ready to answer the media, including social media.

The Southwest Finland regional environmental agency put in place some improvements based on lessons learnt from this event:

- emergency instructions were renewed and clarified. A shorter version of these instructions is available in case of very urgent situation;
- a procedure related to crises management has been developed. To prepare for its deployment, accidents drills are taking place within the authority;
- the means for informing the employees in case of a crisis have been clarified. A new routine is available to inform the ministries and the council;
- weekend duty has been put in place. It will make it possible to react faster whenever needed. The authority used to be only available during office hours.

Besides, the facility at the origin of the event conducted a new environmental risk assessment after the accident. This led to technical changes aimed at avoiding the reproduction of such a discharge:

- installation of a secondary circle to the cooling water system that leaked. All the other remaining open systems were thoroughly verified and changed if needed;
- changes in the automation/monitoring system: installation of additional alarms and efforts to increase their visibility;
- training for employees regarding environmental monitoring;
- improvement of the cooperation with other facilities in the area (during the accident, conductivity alarms identified a problem at a neighbour plant but the information was not transmitted to the involved facility).

Sequence of quick experience feedback

Accident summaries presented in an abbreviated format under the theme "Anticipating emergency response difficulties"

Sinking of a floating roof inside an oil depot

ARIA 45737 - 18 September 2014 - Frontignan (Hérault) - France

Around 7 am, during excessive rainfall, the floating roof on a petrol tank within an oil depot gradually subsided. With a capacity of 30,000 m³, the tank had registered a level of 3,900 m³. Many neighbours complained about the pungent hydrocarbon odours. The depot operator, who had also detected a 300-litre leak in the tank's retention basin, activated the site's internal emergency plan.

Oil depot © Languedoc-Roussilon press

After consulting with BARPI and emergency situation support unit, the Inspection authorities for Classified Facilities validated the operator's proposal to drain petrol from the tank at a slow rate without producing a foam blanket. This decision was based on the following considerations:

- the petrol spread into the retention basin had been pumped and an absorbent had been set in place;
- the results of measurements recorded by the portable gas meters installed around the tank basin proved to be negative and were being used to monitor the evolving situation;
- calculation of the potential pressure surge in the event the vapour cloud were to explode when exposed to free air, given the hydrocarbon concentration and tank configuration, indicated that such an explosion would remain confined within the tank walls;
- producing a truly efficient foam blanket for this configuration was difficult;
- spraying foam out of a cannon was not recommended due to the static electricity and consequential fire risk generated by this kind of procedure.

The operator conducted an analysis of the incident. Under the weight of accumulated rainwater, the floating roof sank and bowed at the middle. Given its low position in the tank, the tank bottom struck the base of the relief valve, causing the valve to open, which in turn allowed petrol to escape (its density being lower than water) towards the top of the tank, further increasing the load. The efficiency of the drain in discharging the water on the roof was examined and the discharge capacity was found to be insufficient. Moreover, its automatic shut-off system, in case of hydrocarbon detection, malfunctioned (thus explaining the presence of a small amount of petrol in the retention basin at the drain outlet).

Silo fire at an insulation board factory

ARIA 46919 - 20 July 2015 - Bourges (Cher) - France

Drainage of the silo © Fire Services

At an insulation board factory, a heat increase was detected around 2:30 pm in a polyurethane dust silo (temperature of contents: 180°C). At 7 pm, the site operator evacuated all personnel, activated the internal emergency plan and notified emergency services.

After exchanges with a silo fire specialist, fire-fighters attempted to extinguish the smouldering fire using high-expansion foam injected both above and below. This response protocol took advantage of the fact that the foam would adhere to dust particles, thus preventing their suspension in air and the formation of an explosive atmosphere. The operation was interrupted however since it was also causing the release of hydrocyanic acid.

Around 11 pm, the operator, in conjunction with first responders, activated the site's fire water network, composed of nozzles designed to insert the diffusion head in the middle of the fire source. At the same time, 2 specialist subcontractors drained the vessel. The blaze was reported extinguished at 12:30 pm the next day. The emergency status was lifted and the draining operation completed that afternoon. Production was halted for 2 days, and 15 employees were made redundant for this period.

Combustion was caused by the presence of craft paper strips and facing material around the silo's central mast and then by the mast's continuous operations. These strips actually wound their way around the mast, which in turn led to a phenomenon of material accumulation and heating. Continued mast rotation produced heat constantly. The temperature of the dust extracted was not monitored and the high dust concentration (over 70%) in the silo prevented early detection of the heating phenomenon. This accumulation of small strips was due to: worn teeth on the blades used to cut out boards, gradual misalignment of boards as cutting proceeded, and insufficient cutting depth. Subsequent to the accident, the operator improved procedures for controlling and maintaining the filter and saw blades. He also optimised the cutting settings and silo operations, in addition to installing a temperature probe at the base of the silo.

Fire outbreak at a storage site for silicone- and solvent-based finished products

ARIA 48235 - 28 June 2016 - Saint-Fons (Rhône) - France

Within a 1,300-m² enclosed logistics facility at a Seveso-rated chemicals plant specialised in silicone products, a (subcontracted) forklift driver was handling a pallet containing four 200-litre barrels of highly flammable silicone oils (siloxanes) when his fork accidentally punctured one of the barrels. He was able to recover a mobile retention device from the neighbouring storage cell, then placed the damaged pallet onto the device and removed it outside the hangar. The leaking product ignited in contact with an unidentified hot spot. An internal fire-fighter grabbed a nearby powder extinguisher and attempted to control the fire. But the blaze spread quickly and took the life of the forklift driver.

Foam blanket © Fire Services

At 11:55 am, the fire detection system relayed an alarm to the watchman's control post, from which the platform's fire-fighting crew was notified. At the scene in less than 5 min, the crew fought the blaze using 2 foam trucks. Given the intensity of the outbreak, the site operator activated the internal emergency plan around 12:10 pm and set up a crisis unit. All 750 facility employees were confined indoors. External first responders reached the site at 12:20 with 69 vehicles and more than 150 fire-fighters. A vast plume of black smoke, visible from afar, was released above the hangar. Two barrels explosions are observed and heard. Residents of a nearby district overlooking the site gathered in a park to observe the unfolding event.

Since the facility was located adjacent to an urban motorway, the Prefect initiated the external emergency plan at 1:10 pm. Primary schools within three adjoining municipalities were placed on lockdown. The motorway and its on/off ramps were closed, causing huge traffic jams. The fire was brought under control by 2:05 pm thanks to extensive foam spraying via the cannons deployed for this purpose. The external plan was lifted at 2:20 pm. One slightly injured internal fire-fighter required hospitalisation, and an employee suffered from heat exhaustion. 30 m² of the hangar were destroyed, and the site remained idle for a week. 60 of the 230 tonnes of finished products were consumed in the fire.

Explosion on a chemical platform

ARIA 48716 - 17 October 2016 - Ludwigshafen am Rhein - Germany

At 11:20 am in an upper-tier Seveso-rated chemical plant located in a port zone, fire broke out on a pipeline carrying a C4 cut of refinery product as maintenance works were ongoing. The subcontracted maintenance company's personnel exited the hazard zone. Safety staff attempted to snuff out the flame using extinguishers. The port's supervisory station notified the local fire department. At 11:30, just after the response had got underway, an adjacent ethylene pipe exploded. A 30-m long section of this pipe was ripped from its anchorage and ejected towards the dock where fire-fighters had established their position. The blaze spread to other flammable gas pipelines and a boat moored at the dock. Exposed to the thermal effect, several other pipes exploded in due course. The 160 fire-fighters on-site fought the blaze using foam. A controlled combustion of flammable gases was initiated. Both of the chemical plant's steam cracking units were shut down, as was a portion of the production units. All raw material deliveries to the site were cancelled. The local population was advised to remain indoors. Around the plant, air quality was being measured continuously. The platform operator announced the accident on its website as well as via social media. The fire was ultimately brought under control by 9:30 pm.

Extinction on a chemical platform, ARR

The human toll was extremely severe: 4 deaths (3 internal fire-fighters, plus a sailor on the boat moored at the port), 7 serious injuries, and 122 more minor injuries. Property damage was also tremendous.

Clean-up and search efforts for a missing person could only begin 2 days after the accident, once all risks to rescue workers due to gas leaks had been eliminated. While searching in the river port basin, the sailor's body was found.

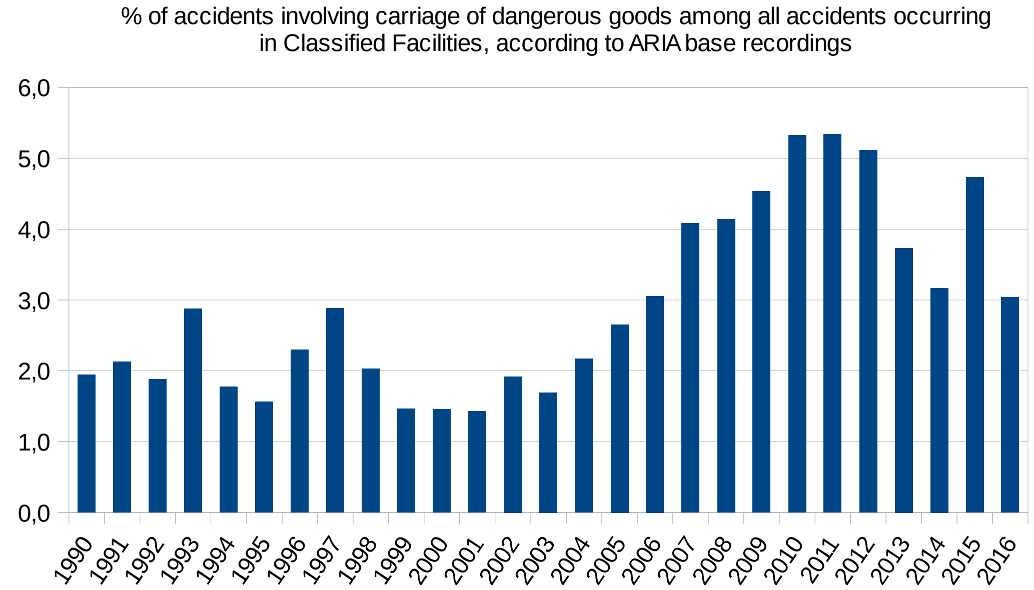
The subcontractor had been commissioned to repair a propylene pipe. All work permits had been appropriately obtained ahead of time. The pipe had been drained, rinsed and inerted with nitrogen prior to undertaking these works. Cutting and welding were necessary at several spots on the line. On the day of the accident, a supervisor with the subcontractor was on-site before any steps were taken. The complete drainage of the pipe to be repaired was verified by means of a 3-mm hole bored with a hand-held auger. Measurements were recorded using a portable gas indicator in order to verify the absence of both hydrocarbon residue and any explosive atmosphere.

In working with an angle grinder, the subcontractor mistakenly intervened on the wrong pipeline. Instead of targeting the drained and prepared propylene pipe, he actually penetrated the line containing a C4 refinery cut. Gas escaped via the notch made in the pipe and ignited in contact with sparks. Presumably, flames then heated an adjacent cross country ethylene pipeline until it exploded by fast decomposition, triggering subsequent explosions and widespread fire.

The operator had been working with this subcontractor for 25 years, and the worker handling this assignment had previous experience with these installations.

Ensuring safety when transporting dangerous goods within classified facilities

Since 1990, a total of 784 accidents involving transportation of dangerous goods within Classified Facilities have been recorded in the ARIA base. The percentage of this type of accident has nearly doubled over the past 10 years.



The transport of dangerous goods is not a "productive" activity, but it remains vital to industrial operations. It generates risks from both human and environmental perspective. As a case in point, over 40% of all accidents related to this activity and recorded in ARIA resulted in human consequences (injuries or deaths).

1. Characteristics of accidents of transport of dangerous goods within Classified Facilities

1.1. Recurrent accidents at specific industrial sites

Accidents involving the transport of dangerous goods might arise several times at the same industrial site. In 16% of accidents involving carriage of dangerous goods concerned Classified Facilities this type of accident had already been recorded on site.

1.2. Have the measures implemented been efficient?

When the same type of accident recurs at a given site, questions are raised over the efficiency of measures adopted and their monitoring by the site operator. An analysis of accidents recorded in ARIA indicates that in some cases, it takes several accidents to occur before the operator actually introduces corrective measures addressing the deep-rooted causes. By neglecting all the organisational and human failures leading to the event, the operator runs the risk of repeat accidents.

Failure to resolve deep-rooted causes may lead to multiple accidents from a single source, though with different effects. Such was the case at a paint and aerosol plant where flawed maintenance scheduling was responsible for two transfer accidents, 3 months apart, originating from defective equipment in two distinct areas (ARIA 43977 and 44336). Another example pertains to a refinery where several accidental spills occurred during tank transfer operations in 2009, 2012 and 2013. The material transfer procedure was revised, coupled with enhanced awareness targeting lorry drivers, yet these measures did not prevent a subsequent incident from arising (ARIA 36546, 42225, 44834). The operator had undoubtedly failed to identify all of the causes involved.

Far too often, several accidents occur before the operator is able to identify their deep-rooted causes and adopt efficient measures. On a logistics platform, it took 3 perforations by a forklift of barrels storing chemical products, before the operator actually identified the deep-rooted cause. As it turned out, the forks on the vehicle were being deployed at full extension when handling smaller containers, so they were puncturing the containers stored behind the smaller barrels (ARIA 44702, 46435, 46559).

1.3. An activity often managed by subcontractors

Accidents involving transport of dangerous goods within Classified Facilities often entail reliance on subcontracted firms. Goods transfer safety is thus being delegated to subcontractors without sufficient control exercised by the operator. Along these lines, the main deficiencies observed in ARIA focus on the following:

- supervision of verification steps conducted by subcontractors, regarding:
  - cleanliness of the tank, specifically the absence of product residue, materials or tools inadvertently left inside the tank (ARIA 33494);
  - condition and type of equipment used to perform the actual product transfer (coupling, piping, etc.) (ARIA 36005);
- supervision of dangerous goods transfer operations (ARIA 47869);
- controls relative to the level of training and risk awareness provided to subcontractors (ARIA 44835).

© Fire Services

2. Factors giving rise to these accidents

Regardless of the actor implicated in accidents involving transport of dangerous goods within Classified Facilities (subcontractors or hired company staff), it is necessary to identify the deep-rooted causes responsible for the event in the first place. When the operator conducts such analysis, organisational dysfunction is often exposed.

2.1. Many control flaws detected

Over 60% of accidents, whose deep-rooted causes were analysed, included deficient controls, particularly on equipment.

© DRIIE

The majority of deficient equipment inspection protocols pertain to the following points: establishing maintenance frequencies, respecting the equipment life cycle, and implementing the appropriate type of maintenance.

Several accidents also reveal organisational flaws in the controls required when proceeding with dangerous goods transfer operations, more specifically: verifying the level of the tank to be filled, identifying the right tank and right coupling, and controlling the condition of machines in service. The presence of a facility technician assigned to oversee and accompany these operations is not always guaranteed.

2.2. Nearly half of all accidents are linked to a human action, why?

40% of all accidents involving transport of dangerous goods within Classified Facilities stem from inadequate human responses; examples include failure to comply with instructions or procedures. While the operator is able to rather quickly spot this type of human breakdown during an analysis, the reasons behind such errors are more difficult to grasp. Once identified, these deep-rooted causes suggest insufficiency in the formation of operator, accounting for 22% of all sampled accidents, as well as lacking, incomplete or inappropriate instructions and procedures for another 28% of accidents.

© DREAL Champagne-Ardennes

2.3. Equipment selection, loading dock ergonomics and risk identification frequently cited as causes of failure

Among the causes observed, are problems related to equipment selection or loading dock ergonomics, especially missing or erroneous indications on controls or couplings. An absence of floor markings inside the parking zone may lead to connection difficulties. The presence of obstacles or clutter in the handling space is another source of accidents. The choice of pipe couplings and materials is also key in avoiding accidents. 15% of accidents with known causes are tied to inappropriate equipment choices.

In order to avoid these organisational problems, risk analysis constitutes a powerful tool available to operators. However, in 19% of cases with identified accident causes, it appears that this specific analysis was missing or incomplete.

For further information, feel free to consult the newsflash entitled "*Delivery of dangerous goods by lorry tankers: Beware of spills*" or the detailed file sheets of accident involving carriage of dangerous goods on the ARIA site at the following address: http://www.aria.developpement-durable.gouv.fr

Accidental spillage of incandescent liquid cast-iron from torpedo wagon

Period 2014-2016

Italy

Metal industry
Dangerous goods transportation
Spillage

THE ACCIDENT AND ITS CONSEQUENCES

The accidents occurred inside two blast furnace plants of an integrated cycle steel making plant where the reduction process of iron minerals takes place with the production of iron-carbon alloys called cast-iron and a secondary material called slag. The reduction products are evacuated through the opening of a casting hole located in the lower part of the blast furnace (melting pot). Then they are collected in a main casting channel, coated in refractory material, where spontaneous stratification of the liquid cast-iron (heavier) from the slag (lighter) takes place. A siphon barrier located at the end of the main casting channel divides and canalizes the reduction products in two casting channels (cast-iron channel and slag channel).

Furthermore, during the ending phase of the casting cycle or in case of shutdown for maintenance, the cast-iron flow, evacuated from the bottom of the blast furnace to empty the melting pot, is conveyed from the main casting channel in a draining channel that ends with a draining hole. The melted cast-iron is loaded in torpedo wagons placed on specific railroad tracks. Such wagons are located at a level lower than the casting floor. Then, depending on the nature of operations, the torpedo wagon can be placed either under the tilting opening (two railroad tracks with two adjacent torpedo wagons) or under the draining hole (one railroad track).

> The torpedo wagons are containers of elongated shape, internally lined with refractory material, moved by means of locomotive, within which the incandescent liquid cast-iron is downloaded at 1300-1400°C for transferring to the steel converter furnace.

The tilting system consisting of a balancer connected to a tilting pot that allows the continuous outflow of cast-iron from a torpedo wagon to another until the end of casting phase.

In this report two accidental events are evaluated : one occurred during the draining phase of the liquid cast-iron into the torpedo wagon through the draining hole (18 cm diameter) and the other occurred during the casting phase of the liquid cast-iron in the torpedo wagon through the tilting system. During both events, accidental spillage of the liquid cast-iron on the ground occurred.

These events generated an emission of airborne particles of reddish dust visible outside the plant.

THE ORIGINE AND THE CAUSES

Draining channel

Draining operations are carried out at every ending phase of the casting cycle, that is once a week. This operation involves emptying the melting pot of the residual liquid cast-iron and performing ordinary maintenance operations, during which the conveying systems are scraped from the solidified residual cast-iron. The draining cast-iron may flow at different speeds depending on various factors which can be either different viscosities of the fluids or obstacles created by chilled cast-iron cakes.

The difference in speed mentioned above caused different falling configurations from the draining hole to the torpedo wagon inlet. Further problems occur also because the chilled cakes, previously formed by the liquid cast-iron splashes on the vertical surfaces of the structure, cause flow deviation resulting in spillage on the sourrounding ground surface outsides the wagons themselves. Yet, another problem is the accidental detachment of the terminal structure of the draining channel. This problem occurs because of mechanical and thermal wear and tear generated by the cast-iron flow.

Tilting

The transfer of the liquid cast iron through the tilting system generates a considerable stress on the tilting-arm. This can result in its breaking and consequently in spillage of cast-iron overflowing from the torpedo wagon. Another cause of spillage has been identified as the chilled cakes collapse from the tilting into the torpedo wagon resulting in the overflowing of the cast-iron.

A further cause of cast-iron overflow and spillage on the ground has been identified in the formation of partially chilled cakes on the torpedo inlet edge which partially obstructs or blocks the tilting system.

FOLLOW-UP ACTION TAKEN

The emergency operations consisted in quickly cooling the surface of the spilled cast-iron with water cannons to prevent its horizontal expansion on the ground. The accelerated cooling generates a surface crust on the spilled cast-iron which mitigates the dust diffusion into the atmosphere. It was not possible to aspirate the emission of dust with the filtration systems on the casting floor because of the height and width of its diffusion.

© ISPRA

In the post-emergency phase, the removal operations of the solidified cast-iron and the restoration of the former operating conditions were carried out.

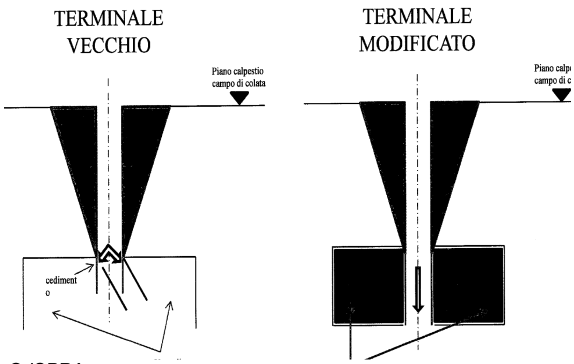
Therefore, some management measure was carried out. Before starting the casting and draining processes, an initial check of the correct operation of the plugging machine (provided with a big syringe that quickly shoots a mixture of refractory resins into the casting hole), was implemented. In fact, in case of emergency, the plugging machine must be ready to stop the casting or draining flow as soon as possible. Moreover, training of the operators has been rescheduled to increase their skills in the process control. In addition, maintenance activities of all parts of the cast-iron conveying structure were increased and rescheduled.

Finally, a groove was carved into both railroad tracks so as to inform the machinist on the correct position - under the cast-iron hole - where the torpedo wagon has to be stopped.

Draining channel

During the emergency phase, the operators immediately left the area hit by reddish emission of dust coming from the lower ground level. The plugging machine was immediately activated to close the casting hole of the blast furnace. Firefighters rapidly cooled down the spilled cast-iron on the ground and extinguished any fire outbreaks with water cannons.

In the post-emergency phase the former draining hole has underwent some structural changes. Indeed the empty area of the vertical discharge channel was filled with refractory cement to convey the cast-iron in a longer obliged pathway hence, reducing the gap from the draining hole to the torpedo wagon inlet.



© ISPRA

Tilting

The emergency procedures activated for the accident occurred in the tilting system were the same as the ones performed for the draining channel accident.

In the post-emergency phase an additional management measure was adopted. The handling arm of each tilting system was punched and uniquely identified with an ID number so as to place it back in its own tilting system once the weekly laboratory mechanical check has been performed. In addition to a visual check of the torpedo wagon when it uploads, an automatic radar system has been set. It warns that the torpedo wagon is about to be filled up to ¾ of its volume.

Finally, the maintenance activity of the tilting system has been increased in order to guarantee the removal of all the residual chilled cast-iron cakes. This activity is performed to avoid flow deviations on the tilting pot due to the solidified cast-iron cakes. It also prevent the chilled cakes from sticking onto the handling arm, therefore creating mechanical overweight or cracking during the hot-cold cycles.

LESSONS LEARNT

Before 2012, these accidental events occurred occasionally and the company focused the correcting measures on controlling the related risks for operators. Since 2012, however, the increase of media attention on relevant accidental events of this industrial plant resulted in significant increase of social, environmental and safety concerns.

Therefore, the plant operator analysed in detail the structural and mechanical causes of the accidents in order to minimize the occurrence of the described events. This decision was taken because of environmental authorities pressure. Moreover, the plant operator carried out further technical modifications to optimize the transfer of the liquid cast-iron, reviewed operational procedures of management and maintenance and increased training for operators.

In conclusion, over the last years, the plant operator realized the importance of environmental concern, for minor accidents as well as for major ones, due increased media attention and, consequently, social commitment. Therefore, the outcome of this situation is that three different stakeholders (authority, media and local citizens) control in different ways the environmental and safety issues of the plant operation.

Fire and explosions of tanker lorries
3 April 2016
Bassens (Gironde)
France

Explosion / BLEVE
Mobile storage
Liquefied gas
Dangerous goods transportation

THE ACCIDENT AND ITS CONSEQUENCES

The site

The accident occurred in the parking area of a road transportation firm. The substances being transported were mainly liquefied flammable gas (LFG) stored in tanks and bottles, along with hydrocarbons contained in tanks.

This site was used for parking lorries, especially at night and towards the end of the week (approx. 100 lorries).


Extracted from an amateur video


© Police

Until 25 November 2013, the site had been subject to a special administrative status, in accordance with the regulation applicable to classified facilities and relative to the storage of gas bottles.

In 2013, the site operator filed a permit application to increase the depot's gas bottle capacity (from 50 to 100 tonnes), which led to the issuance of a Prefect order on 25 November 2013 placing the site above the lower-tier SEVESO classification rating. However, this capacity increase was never implemented.

The parked fleet of vehicles was not taken into account when determining the site classification, nor was it included in the safety report appended to the permit application. In fact, the application indicated that no hazardous substance was being brought to the site and moreover that all parked tanks returned empty, although some LFG transport vehicles might contain a residual quantity of gas or vapours (estimated at between 300 and 500 kg).

The site is located in an industrial zone. The closest industrial installations are located just a few meters from this facility's boundary, i.e. roughly 50 meters from the scene of the accident. The closest dwellings were also in proximity to the site boundary, some 250 meters from the outbreak of the fire and explosions.

Situation prior to the accident

The total quantity of LFG present on-site in the tanks before the accident could be estimated at 150 tonnes, on 30 vehicles, including 19 tanks loaded on semitrailers and 11 tanks on lighter duty vehicles. Three tanks for transporting ammonia, each containing approx. 500 kg of residual gas, were also being stored on-site. Many other vehicles were also parked, including gas bottle carriers and tanks containing flammable liquids.

The accident and its consequences

Fire broke out on sunday 3 April 2016 at 5:37 am on a lorry carrying a 20-m^3 volume LFG tank. It spread to 7 other vehicles of the same type. Two BLEVE events on tanks occurred at 7:14 and 7:33 am.

Four minor injuries were reported among the first responders. Fire-fighters did not hear the whistling noise characteristic of the imminence of a BLEVE which would have alerted them; the response team was set up around 40 m from the point of ignition and protected by the vehicles when the second BLEVE happened. They continued to battle the blaze after this second BLEVE and brought it under control by 9 am. No local residents were adversely affected by the event.

The company's offices, some 200 meters away, and the premises of neighbouring firms bore the brunt of the shock wave (damage to structures, broken window panes at distances of up to 700 m).

Some pieces of tanks, weighing up to several tonnes, were found as far as 100 meters away, yet for the most part remained within the site boundary. The technical control station, at a distance of roughly 50 meters, was hit by a projectile weighing an estimated 500 kg. Many fragments were strewn as far as 250 meters. One fragment weighing approx. 50 kg landed in a garden 1.5 km from the blast site.

Both tanks involved in the BLEVE had contained respectively 1.5 tonnes and 2.5 tonnes of LFG. The total tonnage of LFG destroyed during this accident was estimated at 5 tonnes.

The maximum distance of thermal effect on humans was calculated to be 40 m. The 20-mbar pressure surge effect was felt at a distance estimated at 280 m.

THE ORIGIN AND CAUSES OF THIS ACCIDENT

The time of fire outbreak makes it very unlikely, actually impossible, that the fire was caused by the overheating of brakes, shock absorbers or the engine, even if one of the vehicles had been running late the day before.

An electrical fire outbreak, on either vehicle equipment or personal devices containing batteries like smartphones or e-cigarettes, is indeed possible. Nonetheless, the vehicle construction features coupled with the instructions issued to drivers greatly reduce the likelihood of this hypothesis.

The most probable cause of this accident is malicious act (however the criminal investigation is still underway).

ACTIONS TAKEN

Emergency measures were mandated to the site operator on 4 April 2016, stipulating:

- shutdown of site activity;
- hiring of a permanent watchman;
- notification to cease the parking of vehicles carrying hazardous substances;
- drainage and degassing of damaged tanks and bottles according to a protocol validated by the inspection authorities for Classified Facilities;
- verification of fire-fighting equipment and all electrical installations;
- repairs and inspection of the fence.

Actions to improve safety specific to the lower-tier Seveso rating were also prescribed on 4 July 2016, namely:

- update of the safety report;
- fence reinforcements;
- fire detection, water reserves and cooling devices.

The company relocated its stationary storage of gas bottles to another site by the end of 2016. The site still housed a single installation authorised under the declaration status : a filling station. The facility therefore is no longer governed by the SEVESO regulation, rendering all prescriptions associated with this designation null and void.

LESSONS LEARNT

It is advisable to strengthen the regulatory framework for this type of installation, which is not addressed in the Classified Facilities regulations. Efforts have been undertaken by the General Directorate of Risk Prevention within the scope of the Joint Ministerial Commission on Transporting Dangerous Goods, for proposing updated regulations that would target tighter conditions for storing hazardous merchandise in vehicle depots.

As regards the technical and organisational approach to prevention, monitoring and response, experience feedback has served to propose the following improvements:

- measures to prevent malicious acts like reinforced fences, services of a watchman or supervisor, given the resources to sound an alarm and intervene quickly;
- restrictions to mitigate hazard potential, such as the limitation by type, quantity and duration of presence regarding hazardous substances;
- an organisation that enables, under all circumstances, early action from the operator (intrusion and/or fire detection, emergency preparedness, knowledge of fleet status, quick removal of vehicles);
- pre-established procedures to ensure response in case of an accident and all post-accident management;
- an alarm system for fire-fighters in case of pressure rise in tanks exposed to flames.

When establishing these technical and organisational measures, it is advisable to define the competent administrative authority in charge of control.

Early analysis of technical or organisational changes

An early analysis of technical or organisational changes often proves to be insufficient, or overlooked altogether, resulting in numerous accidents. In many cases, it is simpler and less costly to use existing installations in order to develop or advance a particular process. Such a step however does require an in-depth analysis of the modifications, combined with an accurate identification of the risks tied to anticipated changes.

This document presents a few examples of accidents before revealing the tools available to enable the successful completion of such analyses.

1. Accidents recorded in the ARIA base

1.1. Typology of events

Among the most significant accidents sampled for this study, the following cases merit attention :

- Hastily planned modifications, carried out in the aim of saving time or money, without an adequate risk analysis :

  - ARIA 16632 : Replacement of a 1-kW heating mantle by a 3-kW model on a chlorine bottle in order to raise workshop productivity. 4-kg leak of chlorine.

  - ARIA 31317 : Increase in the colour change frequency for electrostatic bowls inside a paint booth, thus eliminating the possibility of dissipating electrostatic charges between 2 bowl loads. Consequences : 2 deaths, several injuries, tremendous property damage.

- Modifications introduced but not tracked and “forgotten” : ARIA 2900, 43616.
- Evolution accompanied by technical modifications, yet without sufficient risk analysis :

  - ARIA 43685 : Modified nitrogen injection but with inadequate recognition of the presence of hydrogen (insufficient sweeping of the expansion space). Partial opening of a tank roof.

  - ARIA 27467 : Installation of a second cooling circuit, though without a proper backflow preventer, to efficiently separate the two networks. Introduction of glycol in the water supply network.

  - ARIA 32640 : No resetting of instrumentation subsequent to modifications allowing individual compactors to no longer feed one, but several, tanks. Spreading of $ZrCl_4$ following a break in the vent pipe.

  - ARIA 37060 : Modification, consisting of reincorporating manufacturing rejects, that failed to be taken into account in lowering the product ignition temperature induced by the modification. Destruction of a drying oven.

  - ARIA 49121 : Installation of new stirrers, undermining the reliability of temperature probes (electromagnetic disturbances). Runaway reaction, release of ammonia.

ARIA 32640 © DREAL Auvergne-Rhône-Alpes

- Technical modification inducing a change in process settings and leading to a loss of process control:

  - ARIA 22693 : Modification of a mixer to extend its pipes, thus requiring a higher mix temperature to offset the load losses. This temperature increase led to exothermic decomposition of the chemical substances being transferred.

- Poor management of modifications and lack of communication: ARIA 35863, 39354, 40496.

ARIA 43685 © Site operator

1.2. The consequences of these accidents

The study focused on 28 French accidents representative of this particular topic. Though the sample was rather small, certain trends could be detected. Nearly half of these accidents resulted in injuries. Property damage was recorded in nearly 70% of them, and eleven were responsible for a pollution incident.

Consequences	Number of accidents	Percentage
Deaths	1	3,7%
Injuries	12	44,4%
Property damage	18	66,7%
Pollution	11	40,7%

2. Set of tools available

2.1. Full understanding of the history behind the unit or the equipment and its characteristics

Over the life cycle of a given unit or equipment, it is commonplace for modifications to be introduced subsequent to a process update or change in manufacturing protocol. Having complete knowledge of this history is key to making the right choices regarding which modifications to perform. As such, the following questions need to be asked :

- What does the unit produce or what has it been producing over its service life (should production have been discontinued) ?
- Which materials had been used as equipment inputs, which substances had been present ?
- Have the modifications performed been commensurate with the product / equipment characteristics ?
- In the event of modifications leading to a change in process settings (temperature, pressure, etc.), have process controls continued to be maintained ?
- How are the various networks (reagents, water, steam, etc.) laid out, can they still accommodate the planned modification ?
- Has attention been paid to controlling degraded operating conditions (cooling circuit design, retention basins, blowdown systems, etc.) ?
- Are the safety barriers in place still adapted (relief valves, rupture discs, etc.) ?

2.2. Risk analysis for any modification, even one considered to be minor

Risk analysis is critical to any alteration in unit operations. A good understanding of the unit history, along with effective communication between departments and close monitoring of operations, still falls short when not accompanied by a preliminary risk analysis. Third-party expertise may prove helpful in successfully conducting such an analysis.

2.3. Training, organisation, control, communication

Technician training, well-coordinated internal company organisation and effective communication between departments ensure that modifications and controls are being well monitored and moreover serve to answer the following questions:

- Who was doing what ?
- Have modifications been performed ?
- Which controls had been implemented, on which equipment ?

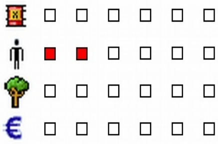
2.4. Procedural updates, written operating instructions, potential modifications

Procedures and instructions offer guidelines for technicians. Producing a document that retraces the history of operations is important as a means by which technicians can relate to the other teams and learn the exact condition of equipment. In association with effective communication, such documents help safeguard the unit's smooth operations.

Explosion of an alcohol tank inside a vinegar plant
11 August 2015
Vauvert (Gard)
France

ATEX
Welding
Risk analysis
Start-up

THE ACCIDENT AND ITS CONSEQUENCES



Inside a vinegar plant, a 150-m³ tank containing 38.5 m³ of an alcohol vinegar mixture exploded around 9:40 am. The 3,000-m² site had been in activity start-up mode, but engineering works were still underway. The tank bottom became detached from the shell. Its upper part, measuring 13 m high, 4 m in diameter and weighing some 3.5 tonnes, was projected upwards, by missile effect. It perforated the building roof and landed 80 m away on a rail line. Two subcontractors were injured, one sustaining serious burns. Both required hospitalisation.

© DREAL Occitanie

Fire-fighters extinguished a fire outbreak in the company offices, most likely due to a compromised electrical installation. Nearby rail traffic was suspended. The vinegar spilled on the floor and was collected in the site's retention basin. The building adjacent to the tank was severely damaged and at risk of collapse. The neighbouring tanks, not fastened to the ground, were deformed either by the explosion blast or subsequent to striking one another. A 42-m² opening was visible in the siding near the tank. The projection through the roof left a 20-m² hole.

ORIGIN AND CAUSES OF THIS ACCIDENT

Hazardous substances present prior to the completion of works

The plant was being restarted following relocation of its installations. More specifically, all of its pipe connections had not yet been finalised. The facility operator had initiated the transfer of activities prior to complete execution of the various on-site works. Ongoing production runs were stored in the tanks while awaiting the hookup step. The operator had validated the policy whereby all vessels containing liquids with an alcohol content of less than 11% were to undergo assembly work without requiring preliminary drainage.

The tank involved had been installed on its base without being fastened. It had been filled 5 months before. The 38.5 m³ contents came from various mixes prepared at the former production site. This volume was composed of water, vinegar, alcohol and acid. The degree of alcohol in this liquid had been estimated at 9%. The planned operation consisted of welding 2 pipe brackets onto the shell. No prevention plan or hot work permit had been issued prior to initiating these works. The 1st weld was set 2.10 m above ground (i.e. 1 m below the liquid level), while the 2nd one was positioned at an elevation of 5.70 m (2.60 m above the liquid surface). The explosion occurred when readying for the 2nd weld. A pressure release noise could be heard by welders just a few seconds before the blast.

Unfamiliarity with the ignition risk

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An expert appraisal was conducted by a specialist body in order to identify the causes of this accident. The first point appearing in the operator's post-accident assessment was that the mix contained in the tank had an effective degree of alcohol near 20%. At this concentration, the flash point of the mix is 36°C. The study indicated that the act of fastening the first bracket by welding, performed below the liquid level, caused local heating. The liquid temperature, initially estimated at 30°C in light of meteorological conditions, most likely rose to a temperature near that of its flash point. The heat created an explosive atmosphere within part of the tank's expansion space. The 2nd weld, which proceeded during the gaseous phase, provided enough energy to ignite the gaseous mix. According to the study, only 10% to 20% of the expansion space volume needed to be at the lower flammability limit concentration in order to trigger the observed effects.

Another possibility is that the current used to perform the weld (TIG) triggered a phenomenon of electroerosion eating away the tank's stainless steel material. This reaction could have produced hydrogen since the liquid mix did contain acetic acid. More specifically, the reaction between steel and diluted acids caused a hydrogen release. As for the ethanol concentration already present in the expansion space, it is possible that a slight addition of hydrogen (with a lower flammability limit at 4%) was enough to render the entire mix flammable.

Moreover, the installation configuration featured a number of conditions needed to generate the observed effects, i.e. :

- a pressure-resistant and non-fragile tank with respect to the shell/dome connection ;
- an elongated and vertical tank shape ;
- a pressure peak encountered during the blast due to gas ignition until rupture of the shell/dome connection ;
- high-speed ejection of the liquid through the tank bottom, thus increasing the propulsion output.

Given the amount of energy available, the shock wave was nonetheless significantly dissipated due to the proportion of energy spent tearing the tank, roof and siding and projecting the tank, thus limiting the consequences of this explosion.

ACTIONS TAKEN

Subsequent to this accident, the plant operator took a number of corrective actions in order to satisfy regulatory compliance, with priority assigned to defining the explosion risk zones. The operator also adopted the following measures :

- preparation of a single document along with workstation data sheets for the purpose of informing employees of the risks present. Part of this document was devoted to the set of measures relative to explosion protection ;
- definition of the ATEX (explosive atmosphere) zoning, giving rise to the implementation of all necessary prevention measures. Accordingly, the operator displayed regulatory posters, including pictograms indicating the presence of flammable liquids in certain tanks ;
- development of a mandatory prevention plan along with a hot work permit system to better supervise all maintenance work or installation modifications.

LESSONS LEARNT

From an organisational standpoint, this accident was due to a combination of several factors, namely :

- underestimation of the ignition risk due to the substantial difference between the actual alcohol concentration (20%) and the expected level (9%). Moreover, it was highly uncharacteristic for an ongoing production run to reach such a high degree of alcohol. The mixes typically used on-site had not exceeded 11% ;
- inadequate preparation of the on-site works: the crew started up without any prevention plan in place or a hot work permit, in violation of the Prefect's authorisation order ;
- lack of concern over the impact of meteorological conditions while works were underway. The concentration level during the pre-works vapour phase climbed close to 2/3 of the lower flammability limit as a result of the high outdoor temperatures (35°C) ;
- absence of any analysis when initiating service at the plant. Start-up occurred without conducting any prior compliance review, as outlined in the Prefect's authorisation order ;
- installation design did not allow for a controlled dissipation of the energy generated by the explosion.

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Release of chemical effluent containing acetonitrile to soil and groundwater

12 May 2015

Grenzach-Wyhlen
Germany

Chemical engineering manufacture
Release
Pollution (groundwater, soil)
Communication
Maintenance

THE ACCIDENT AND ITS CONSEQUENCES

The site where the accident occurred was a Seveso II upper-tier establishment for which a safety report and a safety management system as well as the required on- and off-site emergency plans exist. Under the Seveso III Directive the establishments remains in the same category.

A release of chemical effluent containing acetonitrile from the chemical waste water system in June 2015 led to a groundwater contamination (around 1 ha). Due to the sporadic manner in which this section of the waste water system was used, it was not possible to determine how long the leak had existed. Based on records, the company made a worst case estimate of 557 days, indicating a potential loss of 61 tonnes of acetonitrile. The release led to a contamination of the soil and groundwater.

Wells were sunk to try and recover the contamination through pumping and also to sample the groundwater. Three tonnes of acetonitrile were recovered over a 3 month period of pumping; by which time the concentration had been reduced from 1000 mg/l to < 1 mg/l.

About 500,000 € were necessary for the monitoring and clean up as well as the work to repair and reinstate the foundations of the building.

THE ORIGINE AND THE CAUSES

The technical cause of the release was due to corrosion of the chemical waste water system by the chemical effluent stream. The concrete shaft of the system was lined with a lead coating and tiled with ceramic tiles (cleft clinker). Over a period of time the clinker had become porous and the fluctuation of the pH of the effluent dissolved the lead oxide surface and the lead lining itself. The joints between the tiles are the likely points of initial corrosion. Therefore it was only a matter of time before the concrete wall of the shaft was penetrated and the effluent was released to the soil and groundwater. The release was only recognised when an intrusion of liquid into an energy channel was identified during a regular inspection tour.

Damaged chemical effluent shaft © Site operator

Hole in the floor of the chemical effluent shaft (close-up) © Site operator

The organisational root causes are to be found in events which occurred twelve years previously. The production facility changed ownership in 2003. Within this process the work's own bricklayers were dispensed with and the maintenance of the tiled, clinker surfaces was no longer carried out. Deficiencies in the Management of Change (MoC) processes did not identify the importance of the role of the bricklayers for the plant integrity of the waste water system.

In addition to this the regular 3rd party inspection of the plant did not identify the degraded state of the shaft. This was due to poor coordination between the operator and the 3rd party inspection body. The operator believed that the shaft had been inspected, but the 3rd party inspection body did not understand this to be part of their inspection contract. Thus positive results of the inspection were misinterpreted by the operator.

FOLLOW-UP ACTION TAKEN

The chemical effluent stream was diverted to other inlets. The corroded shaft was replaced by a waste water effluent collection system of a different design.

Initial concerns that the extent of the groundwater contamination could lead to a trans-boundary accident could be dispelled. All of the monitoring stations were negative and the ground water modelling gave no further cause for concern.

The building was investigated with regard to the undermining of the foundations by the effluent release. The damage was identified and repaired.

Wells were sunk to pump the contaminated groundwater and to attempt to recover the acetonitrile.

All other chemical effluent shafts on-site were inspected. Whilst no further leaks were identified, some repair and maintenance work was required.

As a result of this incident, a Geographic Information System (GIS) all underground piping and piping within the energy channel system (i.e. cooling, rain water, chemical effluent and all shaft-systems) is being set up. The aim is to have a complete documentation of testing, investigations, measurements and analyses. This should enable the company to have simpler task in providing the necessary proof of integrity to the authorities in the future.

LESSONS LEARNED

Change of ownership and operational reorganisation can have significant impact on plant integrity and safe operation. Before any function or unit is closed or outsourced, the role and impact of the change of this role should be considered in detail.

3rd-party inspection is a valuable tool for the verification of integrity and safe operating conditions. However the operator is responsible to ensure that the 3rd-party inspection body is given a clear set of requirements for the inspection, that the scope of the inspection is defined, that the physical extent of the plant to be inspected is described and marked on drawings. The 3rd-party inspection should provide clear evidence of what has been inspected and how, and the state of the equipment. A basic and short description of actions to perfom in insufficient.

Preventing and minimising acts of malicious intent

Malicious acts may arise in number of ways within an industrial facility. Such acts may be perpetrated inside the company by a staff member or subcontractor. The notion of industrial facility itself perhaps needs to be broadened, especially in light of the vulnerability of ancillary installations located on city streets (electrical or gas control boxes). Moreover, a computer hacker does not need to physically be on company premises to carry out a malicious act.

This document seeks to answer 2 questions, namely:

- *How is the risk of a malicious act manifested on an industrial site ?*
- *What solutions are readily available ?*

1. Malicious acts occurring in industrial settings

For the period between 1 January 1992 (date of BARPI's founding) and 31 December 2015, the ARIA database contains :

- 1,217 French events spanning all activities with either proven or suspected acts of malice :

Industrial activity	Number of events recorded between 1992 and 2015	Number of events related to acts of malicious intent	Percentage
Classified facilities	25329	881	4%
Dams	332	4	1%
Gas distribution pipelines	1775	50	3%
Transport of dangerous goods by pipeline	442	6	1%
Transport of dangerous goods by waterway	311	40	13%
Transport of dangerous goods by rail	645	7	1%
Transport of dangerous goods by road	2207	17	1%
Household use of gas	824	212	26%

  - The malicious acts recorded on natural gas distribution networks or in the vicinity of gas control boxes (household use of gas) underscore the vulnerability of this infrastructure. Performing works on utility networks (gas, electricity) frequently requires cutting supply lines for the time it takes to complete repairs, which in turn leads to degraded operating conditions that must be managed across the entire site (ARIA 46632, 38534).

  - Moreover, transport infrastructure, whether by road, rail, navigable waterway or pipeline, may also serve as a target for malicious acts (ignited delivery lorries when parked at an oil depot adjoining a Seveso-rated site: ARIA 40052 / hydrocarbon leak on a railcar after a theft at a marshalling yard: ARIA 35847).

- The 881 malicious acts committed at classified facilities were the cause of:

677 fires (77 %)

404 discharges of hazardous or polluting substances (46%)

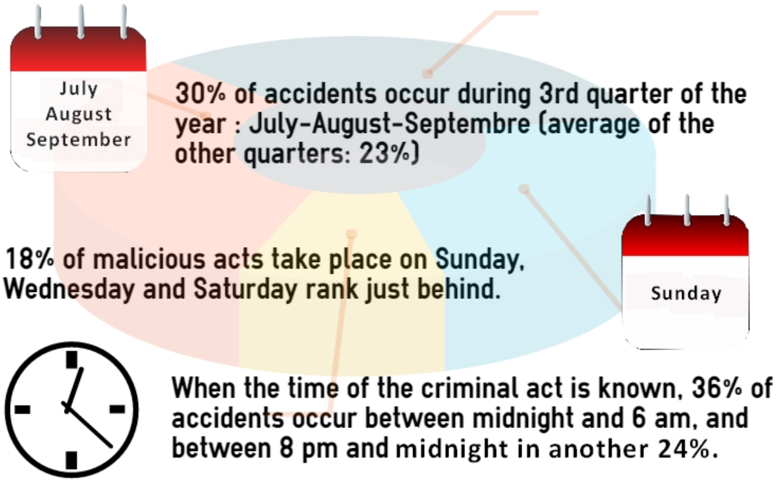
66 explosions (8%)

- Among all these events, only 15 involved SEVESO rated sites, 5 of which occurred in 2015 alone. These following accident scenarios are representative of what has been observed in other facilities :

  - ARIA 47919: Fuel oil spill inside a power plant subsequent to a labour strike ;
  - ARIA 47054: Damage to an electrical box located in the public domain, causing an energy outage at a chemical storage site ;
  - ARIA 46801: Fire outbreak on hydrocarbon tanks ;
  - ARIA 46767: Physical aggression in an industrial gas plant ;
  - ARIA 46508: Fire outbreak at a seed sorting and packaging plan t;

- Another 46 events occurred on industrial sites that were either abandoned or being dismantled. The theft of copper materials on electrical transformers (windings) often leads to spills of dielectric oils containing PCBs.

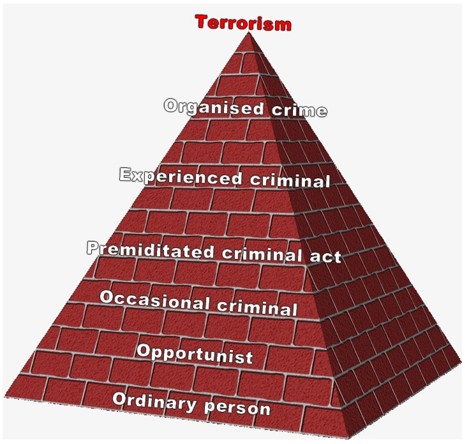
- Timing of the 881 events recorded on classified facilities



- The consequences of events are primarily economic in over 80% of the 881 events studied: based on available information, property damage has amounted to over 2 million euros in 50% of cases, with operating losses being valued at an average of 1.8 million euros for 30 known cases. Environmental pollution consequences can be observed in 46% of all events. Atmospheric pollution (smoke from fire) represents over half of the pollution recorded.

2. Which prevention strategies can be implemented ?

Whether the threat is from cyber attack, ordinary malice or terrorism, it is helpful to assess the risk of malicious acts by examining possible accident scenarios in conjunction with the vulnerability of installations. The nature of the perpetrators must also be taken into consideration when adopting a prevention strategy:



Among existing solutions, we note in particular :

- relying on a watchman performing rounds, the use of fences, video monitoring systems, anti-intrusion alarms or radio wave jamming technology (drones) ;
- strengthening collaboration with police authorities ;
- raising the level of employee awareness to better detect abnormal behaviour and report any observations up the hierarchical chain ;
- auditing of subcontractors or on-site risks (according to the Ineris Institute's guide);
- applying recommendations issued by the ANSSI Agency (https://www.ssi.gouv.fr/) for industrial process control systems and the corresponding computer networks ;
- attention to early-warning information systems (occurrence of malicious acts within a given geographic zone, terrorism alert notified by the SAIP system : http://www.interieur.gouv.fr/Actualites/L-actu-du-Ministere/Lancement-de-l-application-mobile-SAIP, site flyover by unmarked drones, etc.).

? For further information, a statistical accident study dedicated to malicious acts inside industrial facilities may be downloaded from the website: http://www.aria.developpement-durable.gouv.fr/

Two hydrocarbon tanks ablaze subsequent to a malicious act

14 July 2015 (French national holiday)

Berre-l'Étang (Bouches-du-Rhône)

France

Malicious intent
Hydrocarbons
Fires
Pollution
SEVESO facility

THE ACCIDENT AND ITS CONSEQUENCES

On a petrochemical platform, 2 explosions occurred at around 3 am in the storage zone: 2 tanks ignited, causing damage to their floating roofs. The 1st tank contained 11,300 m³ of pyrolysis gasoline (cuts C5 to C9) while the 2nd, located 300 m away, contained 48,000 m³ of naphthalene (light hydrocarbon cuts). In-house fire-fighters, backed up by units in the vicinity, responded massively. The plant operator activated the site's Internal Emergency Plan and notified local emergency services. Thick black smoke was visible at daybreak several kilometres around.

Major fire-fighting resources deployed

The authorities convened a crisis unit at 5:35 am. Police teams closed a motorway access ramp for 7 hours. Both departmental highways leading to the site were closed for a full 12.5 hours. Access to the storage zone was restricted. Municipal fire-fighters arrived at the site periphery around 3:40 am with a contingent of 120 responders and 64 vehicles. Their efforts in support of internal fire-fighters began at 7:30 am. Drawing water from the nearby pond, 6 sprinkling lines 1.8 km long supplied 1 heavy-duty foam vehicle and 3 emulsifier tank cars.

Priority was assigned to extinguishing the 1st gasoline tank. This fire was put out at 4:35 am following a foam assault by the on-site crew. A foam blanket was kept in place until noon. Extinction of the 2nd (naphthalene) tank got underway at 6:20 am and ended by 11:15 am, with the foam blanket being maintained until 3 pm. The floating roof collapsed 48 hours later. Both tanks remained structurally intact. External responders left the scene around 8:30 pm. In all, 170 m³ of foam were sprayed.

Discovery of damage to a 3rd tank

The next morning around 11 am, an inspection of the floating roof on an adjacent tank containing 25,000 m³ of condensates revealed the presence of a fire ignition system and a 4-m² opening running through the central part. The partially submerged roof had not collapsed, and the risk of ignition was still present.

The ensuing pollution created a nuisance for locals

During the drainage phase, the evaporation of hydrocarbons from damaged tanks and their retention basins caused air in the immediate vicinity to be polluted by VOC and BTEX compounds for roughly 10 days.

The air quality monitoring association measured peaks in pollutant concentrations (BTEX, ozone) in the city downwind of Berre as of the very next day. Neighbours complained beginning 2 days after the accident, citing hydrocarbon smells, headaches, itchy eyes, sore throats and runny noses.

Subsequent to the measures adopted to mitigate this pollution, concentrations gradually diminished for 7 straight days after the accident, before dropping precipitously on Day 8, while still remaining above local background levels.

The second tank on fire – © Press

THE ORIGIN AND CAUSES OF THIS ACCIDENT

The initial findings of the accident investigation pointed to an act of malicious intent due to the simultaneity of the explosions as well as to the discovery of detonation devices alongside the damaged tanks and on the roof of the 3rd tank. Property damage amounted to millions of euros. One year later, a suspect, apparently acting alone, was indicted and jailed as part of the case opened for a deliberate destruction of property using explosives and for the transport of explosive substances, with these charges carrying a 10-year prison sentence.

ACTIONS TAKEN

Secure the tanks

The 3rd tank was drained for 5 days following the accident, the 1st tank underwent 2 days of drainage as of the 6th day, and the 2nd tank drained for 10 days beginning on Day 3. All of them were degassed, scoured and ventilated. The structural integrity of their shells was also verified.

Limit soil and subsoil pollution

The tanks' earthen basins contained hydrocarbons that flowed from the storm drain of the damaged roofs. These hydrocarbons thus mixed with the fire extinction water and emulsifiers before penetrating into the ground. The basins of the first 2 tanks were drained, with the fouled earth being excavated and then treated. In all, the total surface area of ground polluted by hydrocarbons amounted to between 0.5 and 2 ha.

Mitigate air pollution

A foam blanket was installed on the first 2 tanks the day after the accident. The 3rd tank was not covered by foam in order to both prevent the roof, already weakened by the explosion, from breaking and enable the judicial investigations to proceed.

The basin of the 2nd tank, which had been filled to the highest level, was pumped as a priority to free its drainage valve. It was also covered with foam to limit the release of pollutants. On the 4th day after neighbours complained, drainage of the 3rd tank was accelerated. Basin contents were redirected from an open-air settlement basin to closed tanks.

Reduce water pollution

An anti-pollution dam was installed at the “Berre’s pond” outlet. Pollutant concentration values at the waste water treatment plant outfall remained normal. The results of groundwater monitoring campaigns south-east of the site revealed the presence of supernatants in wells equipped with piezometers, in addition to high BTEX concentrations in certain spots. The pollution resulting from this accident might have exacerbated the area's pre-existing pollution problems.

On the 14th day, supernatants appeared within a resurgent flow located some 100 meters outside the storage zone, beyond the site boundary. These supernatants were pumped and treated. The treatment of this pollution incident was guided via several orders issued by the Prefecture. Oversight of treatment efficiency as well as the quality of water discharged into the natural environment was instituted as an ongoing process.

LESSONS LEARNT

Civil protection resources may be rapidly deployed, even on a national holiday like Bastille Day. Heightened and constant vigilance is needed over the long run to confront malicious acts or terrorism. The site operator would introduce a robust anti-intrusion monitoring system in the months thereafter and had permanently installed a more stringent site entrance protocol. A comprehensive in-depth strategy was elaborated, focusing on areas of improvement, while at the same time financial investments were earmarked for implementation steps.

In light of this event and the one at Saint-Quentin Fallavier (ARIA 46767), a meeting was arranged on 17 July 2015 between the French Ministry of the Environment and several major operators to address the topic of malicious acts. The Ministry announced that Seveso rated sites would be inspected with this in mind before the end of 2015.

Several areas of emphasis were also included in the action plan, namely:

- Audits by experts with administrative agencies at volunteer sites to analyse the relevance of existing monitoring procedures;
- Scheduling of joint drills with police units and industry groups targeting malicious acts or terrorism;
- Strategy session devoted to the need for transparency with residents living near industrial sites, as well as to the transmission of sensitive data capable of giving rise to a malicious act;
- Request addressed by the Environment Minister to local Prefects for the purpose of accelerating approval of the Technological Risk Prevention Plans.

Sequence of quick experience feedback

Accident summaries presented in an abbreviated format under the theme "Preventing and mitigating malicious acts"

Attack inside an industrial gas plant

ARIA 46767 - 26 June 2015 - Saint-Quentin-Fallavier (Isère) - France

At 9:30 am, a certified delivery driver entered a lower-tier Seveso-rated industrial gas plant. Five minutes later, he drove his light-duty utility vehicle inside a closed hangar used to fill inert gas bottles under pressure. His vehicle contained flammable and combustive gas bottles from outside the site boundary and opened by the driver prior to entering the hangar. The explosive atmosphere created inside the vehicle combusted in contact with an unidentified ignition source. Pieces of the vehicle's interior compartment, blasted during the explosion, struck parts of the building roof and siding as well as some of the production machinery.

Notified by plant security agents, fire-fighters from a nearby fire station arrived at the scene in less than 10 minutes. While surveying the explosion site, they caught the driver in the process of manually opening the valves on industrial gas bottles stored both inside the building (inert gas) and outside (flammable gas). Two responders chased him down and neutralised him. During the action, one of them sustained slight injuries to the arm. Flames were seen spewing from the valves of two flammable gas bottles, which were immediately closed. Fire-fighters and plant personnel stopped all leaks by closing the valves on other open bottles and locking down the installation.

Plant employees were evacuated, while personnel of firms in the vicinity were confined to their sites as police forces secured the entire industrial zone. The crisis unit assembled by emergency responders initiated treatment of trauma sufferers. It should be noted that no employees sustained physical injuries.

The investigation was assigned to the anti-terrorism prosecutor's department. The "*Vigipirate*" alert system was raised to "attack alert" for 3 days in the Rhone-Alps Region. Safety measures were reinforced across all of France's Seveso sites.

Explosion caused by suicide in a pyrotechnics factory

ARIA 48642 - 18 October 2016 - Villeneuve-sur-Lot (Lot-et-Garonne) - France

Around 10:45 pm, the wife of the former owner of a lower-tier Seveso fireworks assembly and storage site committed suicide by detonating the contents of a storage room. A neighbour called the fire station after hearing 2 blasts.

The victim's body was found a few meters from the building. She had deliberately ignited the stored products, which in turn led to the explosion. The 4-m² room contained six 200-mm diameter shells along with 80 aerial maroons 50 mm in size, for a total of 14,468.2 grams of active ingredients. The presence of such a quantity complied with the authorised charge (i.e. 300 kg of products in risk division 1.1).

© DREAL Nouvelle Aquitaine

The video surveillance system was operational, but the monitoring camera lens had been covered by an object (cardboard?). Following the first explosion, this object was blown away, allowing the camera to switch back on: the end of the event could be filmed. Successive explosions ensued for at least 10 seconds, prior to ignition of the flammable components.

The roof was blasted off this storage structure, its door burned and a wall ripped open. Projections of lightweight fragments were limited to a 15-m radius around the room. Both the position of the explosion point, quite far from peripheral land uses, and the existence of surrounding earth walls prevented projectiles from leaving the site.

Since the company's judicial liquidation at the end of 2015 and its buyout by a shareholder in March 2016, the former owner and his wife had been living nearby. The victim was able to gain access to company premises most likely via a passage created by dogs in the fence separating the yard of her house and the storage site. In terms of height, the fence was compliant with regulatory requirements.

As of two days prior to the incident, the site's anti-intrusion alarm had been inoperable. It was scheduled for repair on the day the suicide took place. Since the building door had been blown off, it was impossible to determine if it had been breached or if the victim had an entrance pass. The new operator indicated that subsequent to taking over the firm, he had changed the lock cylinders on some buildings, though not on the premises involved herein.

The most recent site inspection had uncovered the non-compliance of doors and locks, in addition to the remote monitoring station, in comparison with current standard references (Certifications A2P2 and APSAD).

The inspectors' report requested the operator to :

- bring the anti-intrusion alarm back online as quickly as possible,
- verify and repair the fence,
- complete the lock cylinder replacement step on all doors to premises throughout the site.

Compromised marine turbine

ARIA 48048 - 1 October 2015 - Isle of Ouessant (Finistère) - France

Ransomware

During the morning hours, a marine turbine operator noticed that he was no longer able to gain access to his communication interface systems. The installation had been hacked, with the hackers introducing ransomware, a programme that encrypts the data stored on a server, making it unusable until ransom money is paid. Output from the turbine was halted. The facility operator subdued this threat by shutting down the server and then thoroughly cleaning the information system. Operations resumed 2 weeks later. The electrical network had not been disrupted: this incident occurred just a few days after connecting the turbine to the grid.

This marine turbine, submerged at a depth of 55 metres in the Fromveur Strait off France's west coast, is connected by optical fibre to a control room located on the Isle of Ouessant. This room features a satellite connection for performing telemetry with the continent. The operator indicated that the backdoor used by hackers to access the network might have been a man-machine interface on a smartphone that allowed data to be displayed remotely.

Following this event, the operator installed a firewall, bolstered system security with technical subcontractors and removed the mobile interface.

Fire at a recycling firm

ARIA 48396 - 22 July 2016 - Saint-Herblain (Loire-Atlantique) - France

Around 8 pm, fire broke out in a 720-m² building at a waste recycling firm. The site was closed and the watchman momentarily away from his post. The blaze caused one of the power cables feeding the gate to melt, thereby preventing its opening. The watchman had to open the gate manually to enter the site along with first responders, who had been notified by someone outside the firm. A thick plume of black smoke was released. Fire-fighters connected to the hydrants on the lower part of the property. Emergency vehicle drivers were called in to back up the fire-fighting crew. The fire was brought under control around 10:15 pm, and rounds were organised to last all night long.


© Site operator

The roof on the burnt building was damaged, as well as many cabling connections, making it temporarily impossible to continue with sorting and packing activities. The sprinkler heads in place above the press were activated, which protected the press. The other buildings sustained no damage. The fire extinction water (700 m³) was collected in the 1,430-m³ underground retention basin. The 200 tonnes of waste affected by the fire (paper, cardboard, plastics, etc.) were discharged to certified treatment facilities.

The cause of this accident could not be identified. No activity (vehicle use) or hot spot works had been conducted in the building during the week before the fire. The bailing machine present inside the building had been idle and turned off for 3 months.


© Site operator

A malicious act was suspected. Around 7:25 pm that evening, the watchman had noticed intruders within the closed site enclosure. The four individuals had escaped by climbing the fence and then taking off in a car. The blaze ignited during the watchman's break at two distinct spots: one in the stockpile of panel pallets composed of plastic honeycomb polypropylene, the other in the recycled paper containers.

After this event, the operator decided to carry out drills with fire-fighters and provide them with a map of utility networks, plus the locations of the site's fire prevention resources and safety devices in order to facilitate their response in the event of an accident.

European scale of industrial accidents
Graphic presentation used in France

This scale was made official in 1994 by the Committee of Competent Authorities of the member States which oversees the application of the Seveso directive. It is based on 18 technical parameters designed to objectively characterise the effects or consequences of accidents: each of these 18 parameters include 6 levels. The highest level determines the accident's index.

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's 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>

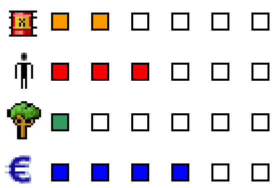
The graphic charter adopted for the presentation of the 4 indices is as follows :

Dangerous materials released

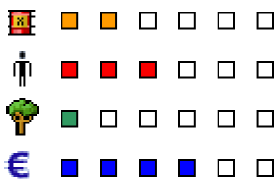
Human and social consequences

Environmental consequences

Economic consequences



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

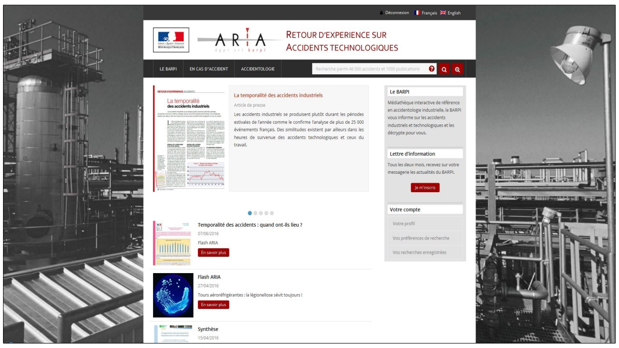
Environmental consequences		1	2	3	4	5	6
Env10	Quantity of wild animals killed, injured or rendered unfit for human consumption (t)	Q < 0,1	0,1 ≤ Q < 1	1 ≤ Q < 10	10 ≤ Q < 50	50 ≤ Q < 200	Q ≥ 200
Env11	Proportion P of rare or protected animal or vegetal species destroyed (or eliminated by biotope damage) 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 environment 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

The ARIA website gets a facelift



For the past 16 years, the ARIA (Analysis, Research and Information on Accidents) website has given the general public access to its database of technological accidents and incidents, as well as numerous publications presenting the lessons learnt from analysing these events.

In 2017, the site is being revised, in both its French and English versions, in order to better meet Web users' expectations and to integrate the latest technologies, with enhanced ergonomics and a completely overhauled search engine.

Thanks to this new version of ARIA, the BARPI is consolidating its role as the **“Interactive reference media library specialised in industrial accident studies”**.

Users can access :

- nearly 50,000 accident summaries (sequence of events, consequences, circumstances, disturbances, root causes – both proven and suspected – actions taken and lessons learnt) ;
- nearly 300 detailed and illustrated accident report presenting accidents of unique informative interest ;
- summaries of accident statistics either by topic or by industrial sector, e.g. automated mechanisms, corrosion, fine chemicals, pyrotechnics, confined spaces, lightning, hydrogen, gas boiler rooms, sensors ;
- a multicriteria search function to find information on accidents occurring in or out of France ;
- saved requests and automatic notification by email should a new element arrive in your fields of interest.

Please feel free to consult the website on a regular basis, as the database expands every year by some 1,200 accidents plus a wide range of publications !

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www.aria.developpement-durable.gouv.fr

industrial accidents database:
> www.aria.developpement-durable.gouv.fr

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