European Union Network for the Implementation and Enforcement of Environmental Law

Lessons learnt from industrial accidents 2023 Seminar

23-24 May 2023

15th edition

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Introduction to IMPEL

The European Union Network for the Implementation and Enforcement of Environmental Law (IMPEL) is an international non-profit association of the environmental authorities of the European Union (EU) Member States, and of other European authorities, namely from acceding and candidate countries of the EU and European Economic Area (EEA). The association is registered in Belgium and its legal seat is in Brussels, Belgium.

IMPEL was set up in 1992 as an informal Network of European regulators and authorities concerned with the implementation and enforcement of environmental law. The Network's objective is to create the necessary impetus in the European Community to make progress on ensuring a more effective application of environmental legislation. The core of the IMPEL activities concerns awareness raising, capacity building and exchange of information and experiences on implementation, enforcement and international enforcement collaboration as well as promoting and supporting the practicability and enforceability of European environmental legislation.

During the previous years IMPEL has developed into a considerable, widely known organisation, being mentioned in a number of EU legislative and policy documents, e.g. the 8th Environment Action Programme that guide European environmental policy until 2030, the EU Action Plan: "Towards a Zero Pollution for Air, Water and Soil" on Flagship 5 and the Recommendation on Minimum Criteria for Environmental Inspections.

The expertise and experience of the participants within IMPEL make the network uniquely qualified to work on both technical and regulatory aspects of EU environmental legislation.

Information on the IMPEL Network is also available through its website at: www.impel.eu

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Executive Summary

The 15th edition of this seminar dedicated to lessons learnt from industrial accidents was held

on 23-24 May 2023 in Marseille, France. The intention was to ease dissemination and exchange of information between inspecting bodies of the Member states. This seminar is organised by BARPI (Bureau for analysis of industrial risks and pollutions) – France, on behalf of the IMPEL network. 310 participants, representing 29 countries, took part in the event. It is worth mentioning that for the first time, 6 UNECE countries (not IMPEL members) attended the seminar.

The topics covered during the seminar were organised in 5 sessions. They were chosen for their relevance to the accidental feedback of the last few years:

- ✓ The importance of source management in the recurrence of waste-related accidents
- ✓ Vulnerability and challenges of information systems
- ✓ Construction, restart, testing: risky steps
- ✓ Environmental monitoring and decomposition of products in smokes
- ✓ Incompatible products/mixtures: how to avoid them?

These topics were illustrated through 18 presentations given mainly by inspectors from various countries and a film produced by BARPI.

One of the session was chaired by a representative of the IMPEL network: Bojan POCKAR.

The return of the feedback forms from more than 100 participants shows a high level of satisfaction, whether on the choice of topics, the content and quality of the presentations or the informal exchanges held around the seminar, strengthening links between European inspectors. As for the financial side, IMPEL contributed to travel expenses of the participants from the IMPEL network (around 55 people). France and the Direction for risk prevention covered the other costs of the seminar.
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LESSONS LEARNT from INDUSTRIAL ACCIDENTS

15th SEMINAR

23 - 24 May 2023 - Marseille

IMPEL
European Union Network for the Implementation and Enforcement of Environmental Law

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Enrich the debate

The European Union Network for the IMPlementation and Enforcement of Environmental Law (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. 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 :

www.aria.developpement-durable.gouv.fr

LESSONS LEARNT

from industrial accidents

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The importance of source management in the recurrence of waste-related accidents

The waste sector has dominated French industrial accident trends by number of events over the last decade.[1] *It is a varied and complex sector in terms of the types of waste treated (hazardous, non-hazardous, fermentable etc.) and the processes used (from simple sorting to hazardous waste treatment). The sector is also characterised by frequent recurrence of events at industrial facilities compared with other sectors. Source management appears to be an important factor in the prevention of industrial risks concerning these varied industrial events.*

The "Waste" business activity group consists of establishments covered by French Classification of Activities (NAF) codes 37 (Sewerage), 38 (Waste collection, treatment and disposal activities; materials recovery) and 39 (Remediation activities and other waste management services). Between 2010 and 2022, this group ranked first by number of events recorded in the ARIA database for 12 years and first by number of accidents for 9 years.

1. Handling non-compliant waste

In the waste sector, the operator of a waste treatment plant must include in its risk analysis the possible presence of waste that does not comply with the specific features of its plant. Unlike operators of production plants, operators of waste treatment plants cannot fully ensure compliance of incoming "objects" with the specifications of their plants. Most often, they cannot control the quality of the sorting that takes place upstream, particularly when this is carried out by the general public. For example, the presence of non-compliant waste (such as lithium batteries, distress flares or aerosols) in non-hazardous waste treatment plants is a latent hazard for which operators must be prepared. Their presence in itself is not necessarily a source of hazardous phenomena, but combined with a disturbance such as the passage of construction equipment or particular climatic conditions, it can lead to an outbreak of fire. Action to educate waste providers and producers may be successful in preventing accident hazards, but operators must consider at the same time the significant hazard generated by the presence of non-compliant waste. Regarding hazardous waste, operators must pay particular attention to the compatibility of waste that will be mixed for treatment.

ARIA 58321 – 10/11/2021 – Vert-le-Grand (Essonne) – France

A fire broke out in the household waste pit of a non-hazardous waste incineration plant. The alert was given by the control room and by the thermal cameras. The operator activated the internal emergency plan. The foam cannons were triggered. At the same time, the employees used two small hose stations. The fire was due to the presence of non-compliant waste (degraded lithium batteries) in the household waste. This type of waste cannot be detected during the inspection phases on reception and while emptying trucks into the pit.

2. Fire prevention

Except in the methanisation sector, where the most frequent hazardous phenomenon is the release of hazardous and polluting materials, fires are the predominant event observed in the waste treatment sector. Reducing the recurrence of events therefore entails reducing the conditions favourable to fire. Operators must identify the conditions that can form the "fire triangle"—heat, fuel and oxygen—and take action to remain outside that scope. Feedback on industrial accidents from the ARIA database shows that in addition to handling non-compliant or undesirable waste at a plant, compliance with regulatory operating conditions is a key factor in reducing losses. The volume of a compost heap can cause self-heating if it induces excessive differences in characteristics between the heap's core and the outside. Overstoring waste at a non-hazardous waste sorting/transit/consolidation facility, especially when there are blockages downstream chain, is conducive to fires, as is waste management at an illegal site that does not comply with applicable regulations. It should also be noted that the higher standard of sorting quality observed over the years can lead to piles of waste that are often drier and more easily ignited.

ARIA 57876: Fire at an ELV centre

ARIA 50359 – 07/09/2017 – La Léchère (Savoie) – France

A fire broke out on a 6,000 m³ outdoor pile of shreeded wood (wood materials collected from waste disposal sites and coated with varnish, paint, glue etc.) at a waste sorting/transit/consolidation facility. A third party alerted emergency services. Multiple non-conformities were found during an inspection visit:

- The amount of wood stored exceeded the authorised limits. The operator said that this was due to the large amount of wood waste received in August when many wood panel manufacturers (recycling of class B wood) and hauliers were on holiday;

[1] Data from the ARIA database as of 26/01/2023

- The wood piles were too close to the site boundaries. In addition to the increased risk of fire spreading, this made firefighter access more difficult.
- Trees and branches near the wood piles helped the fire to spread.

Consideration of climatic conditions is also a crucial factor in the origin of a fire. Events at waste treatment plants occur mostly in the summer when temperatures are highest. Operating procedures must address these particular climate situations along with the various parameters to be monitored (particularly pressure and temperature), and identification of waste that reacts to heat (by decomposition, polymerisation, overpressure etc.) must be performed beforehand to determine the most appropriate storage. The so-called "magnifying glass" effect must also be considered and reduced as much as possible. For example, this may result in a non-hazardous waste storage facility covering waste at a higher frequency than usually observed.

ARIA 59479 – 10/08/2022 – Angoulême (Charente) – France
At about 5:00 p.m., a fire broke out in a car parked in an ELV centre. A large plume of black smoke was visible in the sky. The fire spread to other depolluted vehicles. The event involved 159 burned vehicles, and property damage was estimated to be €150,000. The fire outbreak was due to the intense heat and the mirror effect on the glazed parts of the vehicle. The wind quickly spread the fire to other vehicles.

3. Limiting the consequences of the fire

Even if the above points are taken into account, fires still occur at waste treatment plants. Operators can act to prevent the event from becoming an accident. The operator must first be able to detect a fire outbreak within minutes to ensure rapid extinguishing in the best cases and avoid excessive spread and uncontrollable loss in the worst cases. In too many cases, the alarm is given by neighbours. First-response equipment (such as portable fire extinguishers and small hose stations) must be operational and properly arranged. Employees must be trained in its use. If necessary, fixed fire-extinguishing systems must be installed. It is also important to ensure the accessibility of the site to external emergency services and the availability of water, emulsifiers or inert materials (for non-hazardous waste storage facilities).

ARIA 59898 – 26/10/2022 – Beaupréau-en-Mauges (Maine-et-Loire) – France
At 10:34 p.m., an alarm sent by the emergency telephone system alerted employees of a non-hazardous waste storage facilities that one of the thermal imaging cameras had detected a hot spot in a cell in use. Arriving at the site at 10:45 p.m., an employee began to smother the fire with the stock of soil near the locker. The site manager coordinated the management of the fire using a loader, compactor and shovel. The fire was brought under control at 11:30 p.m. In the absence of flames, layers of soil were spread with the compactor over the affected area. At midnight, the firefighters found that the fire was completely under control and that they did not need to intervene. The affected area was monitored overnight between 2:00 a.m. and 7:00 a.m.

The geomembrane was not damaged. Business activities resumed in the morning.

The alert system, with detection of hot spots by thermal imaging cameras and notification of alerts by an emergency telephone system, enabled good control of the fire and prevented its spread.

illustration photo
ARIA 57253: ***Fire in a non-hazardous waste sorting, transit and consolidation centre***

Fire in an illegal warehouse filled with waste

26/12/2021

Saint-Chamas (Bouches-du-Rhône)
France

Waste
Warehouse (depot)
Fire
Urban area

THE ACCIDENT AND ITS CONSEQUENCES

A fire broke out on a Sunday morning in a waste sorting/transit/consolidation facility in a warehouse with more than 1,000 m² of floor area filled with nearly 30,000 m^3 of waste (plastics, cardboard, wood, tires and more).

The fire had already spread to the mass of waste before the arrival of the firefighters. Their intervention made it possible to extinguish the flames using large amounts of water. In total, 35 fire engines and up to 200 firefighters were called to the scene.

After the first extinguishing phase, smouldering fires inside the piles of waste generated thick smoke. Since the site did not have a water containment basin, it was decided to let these fires burn out to prevent pollution of the Touloubre River and the Etang de Berre, and to set up an emergency water containment basin.

The weather conditions initially allowed dissipation of most of the smoke generated by the fire. In the subsequent days, unpleasant fumes and odours caused significant disturbance in neighbouring municipalities, especially Saint-Chamas and Miramas, and deterioration of air quality.

Given the large amount of waste, inaccessibility of the seat of the fire, the risk of building collapse and the inaction of the operator, the public authorities decided to demolish the building, before setting to work on the piles of waste and spreading them to reach the burning areas and water them abundantly. About 6,000 metric tons of waste (about 7,500 m^3) had to be removed urgently to allow the intervention of the fire engines. The fire was finally extinguished 47 days after the outbreak. About 15,000 m³ of waste was burned.

In the first days, an air quality monitoring station was set up near the site. Bulletins and health recommendations were released to the public. The PM10 particulate matter alert threshold was exceeded on 12 days, but acute toxicity thresholds were not.

A total of 712 metric tons of polluted extinguishing water was recovered and sent for treatment upon intervention of the French Environment and Energy Management Agency (ADEME).

THE ORIGIN AND THE CAUSES

The exact origin of the fire remains unknown. The storage conditions and volume were not in compliance at the time of the fire. The volume of waste the company reported to authorities was less than 1,000 m^3, but in reality, the amount of waste stored was estimated to be 30,000 m^3. The site did not have any fire protection. The operator's business activity was not insured. In addition, the operator was using a waste shredder and sifter without prefectural authorisation.

Following exchanges with OCLAESP (French Central Office against Harm to the Environment and Public Health) three months earlier, DREAL had conducted an inspection and on the basis of this, 12 days before the event, the prefect of Bouches-du-Rhône had issued an order serving formal notice to the company to bring the facility into compliance and, as a precautionary measure, to return to a level of less than 1,000 m³ of waste within the following 17 days. This order included the installation, within 15 days, of the firefighting equipment required by the regulations.

The fire occurred 5 days before the deadline specified in the formal notice.

An investigation revealed that the operator had no competence in the field of waste treatment and was involved in large-scale trafficking (see next section).

FOLLOW-UP ACTION TAKEN

The failures of the operator in the management of the fire and follow-up led the public authorities to step in and replace it, manage the crisis and find solutions to mitigate the impacts on the environment and public, including the following:

- search for outlets for the on-site waste;
- commission companies for surface water analyses and to study the residual structure of the burned building;
- setup of an air quality monitoring station in the immediate surroundings of the site;
- setup of a containment basin, and pumping of the extinguishing water sent for treatment;

- commissioning of the National Institute for Environmental Technology and Hazards (INERIS) for an environmental assessment (performance of an IEM/ERS (interpretation of environmental condition/assessment of health risks));
- prohibition of fishing in the Touloubre River as a preventive measure.

The public authorities have already disbursed €670,000 for the disposal of certain waste in the non-hazardous waste storage facilities during crisis management, the creation of a water retention basin for extinguishing water, the treatment of this water, and the implementation of air quality measurements after the loss.

About 14,000 metric tons of non-hazardous waste are still present on the site awaiting funding for its disposal (estimated cost of €2.8 million).

LESSONS LEARNED

1. Several factors caused the difficulties and consequences of the operations to control the fire and the impacts of smoke and particle emissions in the environment:

- the operator was deliberately illegal, delinquent and ill-intentioned, and did not take responsibility for managing the crisis or even made it more complicated (deliberate bankruptcy, lack of waste tracking records, lack of firefighting equipment, lack of secure access to the site, lack of insurance);
- the building was made fragile and hazardous with many piles of waste around it, limiting direct access to the piles of combustible materials to separate the seat of the fire from unburned waste;
- smouldering fires required risky operations with fire engines at the centre of the piles of waste in order to extract and spread the burning waste to drown it. This type of intervention required the demolition of the steel structure of the building.

2. Launch of the "Clean Slate" operation

Provence-Alpes-Côte d'Azur region has seen the appearance of numerous illegal sorting/transit/consolidation centres for non-hazardous waste (waste from business activities) in the form of warehouses filled with waste, further to the border closures linked to the lockdowns since March 2020. The Occitanie region has also been particularly concerned by this problem. These facilities, of which there are about 25 in Provence-Alpes-Côte d'Azur (including about 15 in Bouches-du-Rhône) plus others in Occitanie and Auvergne-Rhône Alpes, collect, summarily sort and store very large amounts of mixed waste (plastic, wood, scrap) under cover of a simple ICPE (classified facilities for environmental protection) declaration, up to 50 times the maximum threshold of 1,000 m^3.

A large regional operation called "Clean Slate" was launched in Provence-Alpes-Côte d'Azur following this fire to speed up the action of the government on these sites, eliminate the risk of fire, and stop the growth of this type of illegal activity.

Systematic inspections were conducted in the presence of police or gendarmerie forces upon receipt of reports or declarations, followed up by systematic proposals for administrative action:

- orders for precautionary measures issued urgently to stop the supply of waste immediately and reduce the risk of fire and environmental damage;
- formal notice under ICPE and waste regulations;
- administrative sanction orders (fines, escrow, periodic penalty payments, abatement, administrative seals);
- In addition, criminal proceedings have been proposed (in some cases for flagrant offences), in close collaboration with OCLAESP to conduct thorough investigations into some waste operators, carriers or holders.

This regional operation has resulted in:

- about 50 inspection visits;
- about 20 reports of criminal offences;
- more than 50 prefectural orders of formal notice, precautionary measures or administrative sanctions.

Administrative procedures, including in tax matters, have been coordinated between other government and judicial services to maximise the effects, despite the limited administrative resources to deal with this trafficking.

Close collaboration between the prosecutor, prefecture, gendarmerie investigators and DREAL made it possible to quickly identify the main leaders of the network and put a stop to the illegal activity. To date, several indictments have been made, some of them with pretrial detention.

Proposals for regulatory and legislative changes have been submitted by DREAL Provence-Alpes-Côte d'Azur and Occitanie to the DGPR to reduce the occurrence of this type of situation and endow the inspection authorities for classified facilities with powers allowing them to act more effectively and quickly when criminal actors are discovered. Chapter 2 of the multiyear inspection strategic guidelines for 2023–2027 addresses this subject.

A "waste trafficking" unit at DREAL Provence-Alpes-Côte d'Azur was created one year after the outbreak of the fire to provide specific inspection forces for such offenders and situations.

The results of the operation were the subject of communication by the prosecutor in the media.[1]

[1]https://www.paca.developpement-durable.gouv.fr/dechets-illegaux-la-dreal-paca-met-tout-en-oeuvre-a14806.html

Explosion of a tank filled with liquid hazardous waste

27/07/2021

Leverkusen

Germany

Waste

Explosion

THE ACCIDENT AND ITS CONSEQUENCES

On July the 27th 2021, an explosion occurred in a tank field of nine tanks belonging to the hazardous waste incineration plant of a chemical park in Leverkusen, Germany. The explosion induced a fully developed fire of a part of the tank field. Thirty-one persons of the staff were injured and seven were found dead. There were no injuries outside of the establishment.

The hazardous waste incineration plant is part of a waste management centre consisting of a landfill for industrial waste, an industrial wastewater purification plant, waste treatment plants, and waste storage facilities. The plant is part of an upper tier Seveso establishment.

The tanks contained hazardous liquid waste from different operators of the chemical industry waiting for incineration. Waste from different tanks could be mixed because there was a direct pipeline connection between the tank field and the waste incineration installation.


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THE ORIGINE AND THE CAUSES

The explosion occurred in a temperature-controlled tank (50 m^3) containing 16 m^3 of liquid waste with organic phosphorous and sulphur compounds from a Danish pesticide production facility. The main component of the waste was O,O-dimethylhydrogendithiophosphate. The tank was filled with the waste the day before at noon. During the night, the operating staff recognized that the waste was self-heating and they tried to inject it into the incinerator but failed because of technical problems. They decided to wait until the next morning to try again. During that time, they cooled the tank from outside with water and from inside with oil but that was not sufficient. The temperature rose to 90 °C until the next morning at 9:15 am. Afterwards temperature and pressure increased rapidly, the pressure compensating valves could not level out the pressure anymore and the rupture disk of the tank was not sufficient to compensate for the exponentially rising pressure. First, the tank exploded physically, and after contact with oxygen from air, the waste cloud exploded chemically. Eight of the nine tanks in the tank field were destroyed by the explosion and the following blaze but there was only small damage at the incinerator itself.

A nearby 220 kV electric power line was torn because of the explosion. As a result, the fire brigade had to wait until a specialist of the energy supplier grounded the power line. Afterwards 360 action force of the fire brigade extinguished the fire within two hours after the explosion. The smoke cloud was still visible beyond the geographical area of the city. Indications of smut and particle deposits came from different districts of the city. A specialised team of the Environmental Protection Agency of North-Rhine Westphalia took samples of smut and particle deposits as well as soil, grass, and swipe samples. These samples were analysed for PCDD, PCDF, PCB, PAH and 450 potential waste born substances. The results showed no significant pollution outside of the establishment. Results of PCDD and PCDF measurements by the operator and by Greenpeace were in the same order of magnitude.

The explosion is under investigation of the prosecution. Up to now there are two causes of the explosion under consideration:

- the potential of the waste for self-decomposition under exponential increase of temperature and pressure was underestimated. The waste was stored above the self-accelerating decomposition temperature (SADT) ;
- not all needed information on temperature sensitivity, self-decomposition, self-heating, and volume expansion of the waste was delivered by the waste producer. In addition, not all delivered information was completely available for the operating staff.

This is not the final result because the investigation is still ongoing, but it gives valuable information for a restricted re-start of the waste incineration.

FOLLOW-UP ACTION TAKEN

The Danish Environmental Protection Agency (EPA) delivered the following information. The waste is a dark brown liquid, smelling of rotten eggs (H2S). It consists of O,O-dimethylhydrogendithiophosphate (CAS nr. 756-80-9) and a number of bi-products from the synthesis of insecticides. General properties: unstable (during cracking, spontaneous ignition of cracking products / gases can occur); flammable; corrosive; toxic (cat. 4). Classification: flammable liquid, cat. 3, UN 2920. Handling and storage: for a stored mixture, it must be expected that it can contain a considerable amount of hydrogen sulphide, which may be released unpredictably on handling. The mixture is of limited stability. Protect against heat from sunshine or other source. Store at temperatures below 40 °C. Stability: the mixture reacts with water. Contact with water should be avoided. Heating of the mixture will evolve flammable, toxic or harmful and irritant vapours.

After the accident, the Danish EPA delivered the following additional information: the company was ordered to check the transport classification. New tests have been performed by DEKRA (UK), and it is concluded that the substance is candidate for classification as a self-reactive substance type F, and it requires temperature control during transport. Based on the report from DEKRA, the company's safety adviser has prepared proposals for a new safety data sheet and transport classification, which have been sent for approval by DEMA (Danish Emergency Management Agency). The UN number is proposed to be UN 3239: self-reactive liquid type F, temperature controlled. Safety Data Sheet (new in draft): H242 heating may cause fire; P234 keep cool in original container; P411 store at temperatures not exceeding 30 °C (previously 40 °C, cf. SDS Nov. 2020).

The operator of the waste incineration installation implemented new rules concerning waste specification and communication of needed information. New analysis methods for temperature sensitivity and self-decomposition potential of the waste products were implemented at the intake control of the incineration installation. The number of waste streams were limited to 31 liquid waste products without self-decomposition potential and without storage in tanks for recommissioning of the incineration plant. New waste streams and the operation of tanks for liquid waste will only be allowed after assessment by external experts and verification by the State Environment Protection Agency.

LESSONS LEARNED

In addition to that, all possible risks of accidents with waste were taken into consideration, and all measure to prevent the consequences of these risks were considered and assessed. The following items describe these risks:

- wrong declaration of the waste by the original producer;
- wrong waste and hazardous materials transportation legislation classification;
- change in the composition of the waste;
- insufficient analytical description of the waste;
- insufficient information flow from the original producer over the waste reception unit to the operating staff of the installation;
- insufficient waste intake control at the reception unit;
- mix-up of waste streams;
- intermixture of reactive wastes;
- insufficient observing of safety measures;
- technical problems with the incineration installation;
- insufficient danger prevention measures.

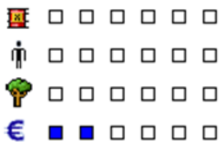
These potential risks were analysed and assessed with the aim to prevent hazards for the reduced recommissioning of the incineration installation.

Another lesson learned was that ecological and toxicological requirements for the handling of hazardous waste play a major role in the regulatory framework while there is not enough attention for safety requirements. There still is a need for action from policy, administration, and waste trade associations to adapt the rules.

Collapse of a silo in a non-hazardous waste incinerator
29/11/2021
Toulouse (Haute-Garonne)
France

Waste
Silo
Corrosion
Ageing

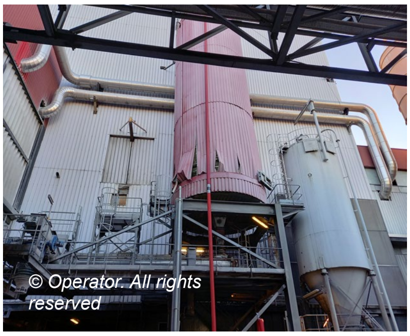
THE ACCIDENT AND ITS CONSEQUENCES



This non-hazardous waste incineration plant burns household waste generated by a large part of the Toulouse metropolitan area, non-hazardous waste from businesses and infectious clinical waste.

The site is located in an urban area and has 4 furnaces with an authorised incineration capacity of 330,000 metric tons per year. The heat produced by waste incineration is used to supply a heating network spanning several tens of kilometres (district heating and domestic hot water) in several Toulouse neighbourhoods, including the "Cancéropôle", as well as a steam network directly supplying the laundry and the sterilisation unit of Centre Hospitalier Universitaire (CHU) de Toulouse.

At about 6:30 a.m., at the start of unloading operations, a silo measuring 15 m in height (25 m with supporting feet) and containing 130 metric tons of RPIFHW (Residues from the Purification of Incineration Fumes from Household Waste, in powder form, considered to be hazardous waste) collapsed on its base.



Damaged RPIFHW silo

When it collapsed, the silo came to rest against the building housing the fume treatment plants located just behind it. In addition to the risk of the silo spilling, the operator feared that it might collapse onto nearby facilities—an activated carbon silo (30 metric tons) and steam pipes—and that they might be damaged.

Operations to secure the silo were quickly performed by the operator with the support of emergency services:

- establishment of a safety perimeter;
- securing the silo to the adjacent building by technicians after validation of the anchor points, and slinging to a permanently present crane;
- monitoring of silo movements with a laser rangefinder;
- installation by firefighters of a water curtain at the activated carbon silo;
- installation by firefighters of water cannons ready to remove dust in case of collapse of the RPIFHW silo;
- 24/7 monitoring and watch.

The plant was shut down while diverting the RPIFHW backup disposal system (as access to it was too close to the silo). One of the backup boilers was started up and the ovens operated with burners to maintain the supply to the CHU steam network and a minimum amount of heat to the heating network. To compensate, the operator put the backup boilers in the heating network into operation. Nevertheless, several housing units were affected for a few days.

The diversion of the RPIFHW backup disposal system (carried out a few days later) made it possible to restart 2 and then 3 furnaces (out of the 4 in the plant) for the treatment of household waste but at reduced load to limit the production of RPIFHW. The plant operated at less than 40% of its capacity for several days. A diversion of household waste, waste from businesses and infectious clinical waste was organised.

The backup system made it possible to recover the RPIFHW in big bags. The procedures for storing these big bags are governed by the order on emergency measures. The disposal route was changed as the RPIFHW was packaged in big bags, which no longer allows its treatment by the usual treatment plant.

Once the silo was secured, emptying operations were initiated. First performed from the top of the silo (by pumping), these quickly proved ineffective. Two weeks after the event, the operator tested emptying the silo from the bottom by restarting the planetary screw.

The operation was validated by inspection subject to the installation of misting systems and gauges for measuring dust fallout on the perimeter of the site. Finally, the silo was emptied without difficulty by way of the planetary screw, and was completely emptied in less than 2 days.

The direct damage of the accident is estimated at more than one million euros and the indirect damage (operating losses, ash management, etc.) at more than 1.5 million euros.

THE ORIGIN AND THE CAUSES

The silo had been installed in early 2000 to replace an existing silo. There were no obvious signs of ageing. However, heat insulation around the silo masked the walls, preventing any visual detection of any anomaly.

The origin of the incident did not relate to an overload because the silo could contain much more RPIFHW than the tonnage present when the event occurred. It could contain up to 210 metric tons of RPIFHW, but the authorised amount had been limited by prefectural order for several years, amounting to 130 metric tons to avoid a Seveso classification of the site.

The silo was dismantled and cut up. The initial observations showed that the walls were thinner at the bottom of the silo, at the site of the collapse, leading to an assumption of chemical corrosion at the lower crown of the silo.

Samples of the corroded walls were sent for analysis to the Technical Centre for Mechanical Industries (CETIM). The report:

- provided evidence of corrosion of the silo steel, which did not have anti-corrosion protection (paint coating type) in the weakened area;
- noted the presence of more marked degradation on the internal surface of the silo (RPIFHW side);
- also specified that the chlorine in the RPIFHW could be aggressive enough, in the presence of moisture, to allow the corrosion process to begin. Nonetheless, CETIM experts believe that the rate of corrosion (determined from electrochemical measurements) cannot alone explain the loss of material observed;
- finally underscored that a thin coating (epoxy paint type) was identified on the internal surface of the silo on undeformed areas of the silo and concluded that this type of coating (which was originally present on the internal surfaces of the silo), although generally very resistant, had more limited mechanical strength (wear, for example).

FOLLOW-UP ACTION TAKEN

An emergency measures order was signed to govern the procedures for storage of RPIFHW in big bags on the site, as well as the implementation of additional preventive measures for silo emptying operations (pre-positioning of water curtain devices to prevent the dispersion of RPIFHW and specific arrangements for the stormwater drainage system).

A detailed incident report was also requested. A "hot" inspection visit was conducted the day after the collapse to determine the measures to take and thus the requirements of the emergency measures order. A second visit, focusing on the incident's "cold" experience feedback, took place 6 months later.

The subject is about to be closed 18 months after the event. A new silo was ordered with a capacity of 200 m³ (instead of 300 m³ for the old silo) and special anti-corrosion and abrasion-resistant coating. It should be delivered and installed in March and April 2023. However, discussions are still ongoing between the operator and the inspection team about the heat insulation that the operator is again planning around the silo.

Although already included in the operator's maintenance programmes, an additional prefectural order is currently being prepared and imposes provisions similar to those of the ministerial order of 04/10/2010 concerning the monitoring of equipment ageing.

LESSONS LEARNED

The emergency services mobilised in large numbers and provided the operator with significant human and material resources very quickly.

Regarding communication, it was decided to inform the members of the Site Monitoring Commission (CSS) from the outset of the incident. As this was the first incident the CSS was made aware of, this communication action proved "counterproductive" in the early stages, as residents sought information directly from the operator, which was in full crisis management. The organisation of meetings (by videoconference) of the CSS committee in the days after the start of the event made it possible to respond to the concerns of residents in the end.

From a regulatory perspective, since the silo of RPIFHW had a volume greater than 100 m³, the provisions of the ministerial order of 04/10/2010 concerning the prevention of risks related to the ageing of certain equipment could have applied to the waste (note that RPIFHW is associated with section 4511, corresponding to hazard statement H411, in the context of the determination of the Seveso classification (or not) of the site in accordance with technical guidance on the consideration of waste for the determination of the Seveso status of an establishment). Even if similar requirements are imposed on the operator by additional prefectural order, the question of the applicability of the provisions concerning the ageing of certain waste containing equipment arises, as the latter ultimately has the same physicochemical characteristics as "new" products.

Recurring fires at a waste facility
March 2018 – January 2023
La Ferrière (Vendée)
France

Waste
Fire
Recurrence

THE ACCIDENT AND ITS CONSEQUENCES

Packaging waste from all over France's Vendée department as well as four communities in the neighbouring Loire-Atlantique department is sent to a single sorting plant that was built in 2016. The mixed packaging waste is delivered to the plant in plastic bags.

Each day, an average of 67 lorries unload waste at the plant, which is authorized to take in 30,000 tonnes of waste each year. The plant is subject to registration under heading 2714 and to reporting under headings 2712, 2715 and 2716.

Forty-eight outbreaks of fire,[1] an average of about 10 per year, were reported at the plant between March 2018 and January 2023. Nearly 40% involved an explosion heard by the plant's technicians.

More than three quarters (37) broke out on the metal baler used to compress pre-sorted metal waste into dense, stackable blocks in order to save on storage space. Around 10% (5) occurred on a baler used to compress pre-sorted plastic and cardboard waste into bales.

In other words, nearly 9 in 10 occurred on machines used to compress sorted waste.

All the fires were successfully extinguished. In one instance, the public fire brigade was called in, but the technicians had brought the fire under control by the time they arrived.

In the majority of the cases, damage from the fire was limited to waste and the plant resumed operations quickly.

THE ORIGIN AND THE CAUSES

The fires on the metal baler were most likely caused by electric batteries, small gas bottles (such as those used for camping), aerosols or emergency flares.

Such non-conforming waste materials can lead to:

- incompatibilities or chemical reactions;
- mechanical sparks;
- overheating;
- autoignition;
- explosions during compression.

FOLLOW-UP ACTION TAKEN

The inspection authorities for classified facilities increased the frequency of inspection at the plant and focused their attention on the management of fire risk. They conducted four inspections over a two-year period at the plant; under normal circumstances inspections are scheduled only once every seven years.

They noted the large number of fires that occurred on the metal baler and found that the conveyor belts above it were made of an inextinguishable material that could spread flames in the event a fire was not brought under control quickly.

No regulatory violations were found.

In their inspection report, the authorities requested the implementation of an action plan to prevent fires and mitigate their consequences. The measures proposed by the plant operator were set out in an additional prefectural order.

The plant operator implemented a number of technical measures, in particular:

- installation, in 2019, of a manually operated sprinkler system inside the metal baler;

[1]These incidents are reported here: ARIA 57875, ARIA 57921, ARIA 57922, ARIA 57923, ARIA 57924, ARIA 57925, ARIA 57931, ARIA 57937, ARIA 57941, ARIA 57944, ARIA 57948, ARIA 57949, ARIA 57950, ARIA 57951, ARIA 57954, ARIA 57956, ARIA 57958, ARIA 57961, ARIA 57964, ARIA 57966, ARIA 57968, ARIA 57969, ARIA 57970, ARIA 57983, ARIA 57984, ARIA 57987, ARIA 57988, ARIA 57992, ARIA 57997, ARIA 57998, ARIA 57999, ARIA 58000, ARIA 58005, ARIA 58332, ARIA 58409, ARIA 58770, ARIA 60180, ARIA 60520, ARIA 60521, ARIA 60522, ARIA 60523, ARIA 60524, ARIA 60525, ARIA 60531, ARIA 60532, ARIA 60533, ARIA 60541, ARIA 60544.

- addition of a thermal imaging camera and flame detectors;
- accumulation of a stock of additional fire extinguishers;
- inspection of the suppression system once every six months.

Organizationally, the operator:

- enhanced on-site training on the fire suppression system;
- strengthened communication with local authorities regarding sorting instructions;
- conducted two summertime collection drives for obsolete maritime pyrotechnics (hand flares, parachute rocket flares and smoke signals).

As the previous fires had been extinguished quickly, installing conveyor belts made of an extinguishable material was not deemed necessary.

The operator is experiencing difficulties in implementing additional measures to improve sorting and thus reduce the amount of non-conforming waste in the metal baler.

Technicians assigned to the plant's quality control stations only inspect batches reported as questionable by the sorting machine. However, as gas bottles and aerosols are made of metal, they are not identified as problematic. As a result, there is no way for the operator to identify incoming non-conforming waste. The sole check for non-conforming waste is the one conducted upstream by the workers in charge of collecting the bags.

LESSONS LEARNED

The presence of non-conforming waste is intrinsic to the operations of a non-hazardous waste sorting/transit/consolidation facility and leads to fires in waste compactors. Although the operator cannot easily control the quality of sorting upstream of the plant, which is essentially the responsibility of users and communities, it can control:

- the quality of on-site sorting by developing more efficient machines;
- early detection of fire with the appropriate equipment and materials, whether in terms of their number, location or characteristics;
- fire intervention by implementing a sufficient number of dedicated (and even automatic) systems at the appropriate locations;
- the right information and training of all its technicians, especially those working near the compactors.

In addition to these measures, extra attention must be paid to waste produced by seasonal (gas bottles used for camping, etc.) and local activities (proximity to the coast in the case of emergency flares, major sporting events in the case of smoke signals, etc.).

Vulnerability and challenges of information systems

Presentation of the study : “Status Quo: Safety & Security in (Seveso-) Establishments”

The increasing digitalization of production processes is also influencing the requirements for establishments that fall under the Seveso Directive.

Attacks on office IT are becoming more and more frequent and sophisticated. Based on the increasing digitalization of production processes this also becomes a Problem in our Production IT (named Operation Technology (OT) in the following).

The first time the process industry was confronted with this issue was in 2010, when a Virus called “Stuxnet” destroyed the centrifuges of Iran's nuclear enrichment program. However, for many operators, this was still a long way off because it was presumably a secret service attack with a highly specialized (and very expensive) virus.

The next wake-up call (at least for the German industry) was in 2014 when a virus destroyed a blast furnace because it could no longer be controlled and the safety equipment no longer reacted reliably.
The latest major escalation occurred in 2017 when hackers attempted to destroy a petrochemical plant in Saudi Arabia by taking control of its safety systems. Fortunately, the attackers made a mistake in the programming of the Safety System, which led to errors in the software, and the plant was shut down instead of blowing up. This was a novelty, as Safety-Systems were often considered isolated or at least somewhat separated from the normal OT and therefore uncompromisable.

To sum this up: nowadays attacks on IT or OT of establishments (or other plants) are part of the normal hazards cape and can cause major accident. Therefore hackers could be able to manipulate process parameters, trigger malfunctions in IT or OT, and much more, which could lead to releases of hazardous substances, fires or explosions. All this leads to hazards to human health or the environment.

There are many examples of successful intrusion into the IT/OT structures of companies worldwide. Fortunately, many attacks focus currently on the office IT since it is easier to make money out of it, but this is mostly due to the intensity of the attackers, not to the technical possibilities.

An example from 2022 for this is a tank storage plant in Germany (Seveso Site) whose office IT is mainly installed in a non-European parent company and which was the origin point of the infection by a ransomware Trojan. Since, at the moment of the ongoing attack, it could not be ruled out how far the attackers had penetrated the Systems (IT or OT or both), all connected tank terminals were shut down with drastic impact for many German gas stations. The extent to which the attackers could also have taken over the storage plants themselves can no longer be clarified (IT-Forensic is often very difficult cause of the possibility that every evidence on the infected computers can be tempered with), but the operator had no possibility to eliminate this scenario. This led, among other things, to the suspension of the planned future remote maintenance operation (no more people on the site) and a drastic increase in the IT/OT-Security budget by the parent company.

The implementation of the Seveso Directive into German law places an obligation on the operator, analogous to Article 5 (1), to take all necessary measures to prevent major accidents and to limit their consequences for human health and the environment, and in doing so also to consider the intrusion of unauthorized persons as a possible source of danger.

To support the implementation of this requirement the KAS (Commission on Plant Safety) published the KAS-51 a high level Guideline for the subject of “unauthorized interference”, but the concrete specific technical implementation of this topic is often difficult in Germany, as the operators are “free” to choose their technical standards. As a result, there are various technical regulations in usage, such as the "BSI-Grundschutz", IEC 62443, NIST / NERC Framework or the ISO 2700X.

To address this problem, the BSI (Federal Office for Information Security) and UBA (German Environment Agency) published a study in 2021 “Status Quo: Safety & Security in Establishments” that considers the possibility of unauthorized interference as a potential source of danger.

The problems in the system between humans - technology - organization are described, new challenges and risks are unveiled and existing national and international specifications for safety and security are presented.
The study comes to the conclusions that a variety of theoretical frameworks already exist. However, the application of these principles is often not yet routine in the organizations. In interviews with stakeholders such as operators, experts or competent authorities, it became clear that in larger organizations the issue is mostly well addressed. In smaller organizations, there is still a need for further implementation. The reason for this is often a lack of staff with the necessary qualifications or a lack of awareness of the problems.

On the one hand, the study aims to raise awareness of the problems that arise. On the other hand, the study shows simple approaches to solutions in order to increase security in organizations with regard to intrusions by unauthorized persons.

Furthermore, the study provides an overview of current technology trends and their potential impact on OT-Security. A management framework needs to be established to guide the OT-Security process and a risk analysis should be conducted to evaluate which additional OT-Security measures should be taken. For example, before integrating new technologies into a cyber security concept, it should be determined how they can be integrated into the existing network architecture.

An exemplary risk analysis according to IEC 62443 and necessary measures derived from it according to BSI-IT-Grundschutz can serve as a blueprint for other plants and organizations.
As a result, guidance is provided for operators, competent authorities and experts on how to address this topic when preparing a major-accident prevention policy or a safety report.
The presentation is intended to provide suggestions for their application in the prevention of major accidents.

Link to the study
Status Quo: Safety & Security in Störfall-relevanten Betriebsbereichen (bund.de)

Intervention of the French National Agency for the Security of Information Systems

The French National Agency for the Security of Information Systems (ANSSI) is the national authority for cybersecurity and cyber defence. Its mission is to build and manage the protection of the nation against cyberattacks. Reporting to the Secretary General for Defence and National Security (SGDSN), the Agency is a service of the Prime Minister, and its activities are exclusively defensive. The Agency works mainly for three types of clients: government agencies, critical national infrastructure providers and operators of essential services. It has a staff of 573 (on 31 December 2021).

ANSSI has 4 main missions:

- Defend: the Agency steps in to stop attacks on the systems of a client or another victim when the situation requires it and to guide the reconstruction of information systems. It plays the role of "cyber firefighters", and its mission takes many forms: remote assistance, sending experts on-site etc.;
- Know: the Agency constantly assesses threats and risks in cyberspace and develops methods and tools to address them, particularly through its laboratory activities;
- Share: the Agency helps raise awareness of digital risks and disseminates information to various audiences (experts, individuals, business leaders etc.) about best practices (agency guides, SecNumacadémie online training, Cybermoi/s annual awareness campaign etc.);
- Support: the Agency assists the government in implementing public policy on cybersecurity and in developing an ecosystem of trusted product and service providers in the field of cybersecurity.

Industrial control systems (ICSs) are used by many critical national infrastructure providers in sectors such as transport, energy, defence, health, food and manufacturing. ICSs are considered complex and critical assets. They encompass many aspects, such as business continuity, long service life, and higher intrinsic value than traditional information technology systems.

Technological development, particularly with the advent of Industry 4.0, is leading industrial networks (operational technology, OT) to interconnect with traditional IT networks and the Internet. This interconnection helps to increase the attack surface of ICSs, although they were designed to operate in isolation.

Cyber espionage campaigns pose a relatively continuous threat over time. Several state-sponsored groups of attackers have the technical capabilities to target industrial control systems. Such campaigns have been observed and aimed at obtaining industrial data or conducting reconnaissance on industrial networks (such as the size of the network and its organisation). Prepositioning and destabilisation, particularly affecting the ICSs of power grids and production units, are serious threats that are driven by international tensions. Several governments have already implemented prepositioning actions on power grids.

Cybercriminal groups and ransomware pose an additional threat to ICSs. The crucial need for business continuity of industrial systems can be perceived by attackers as an asset to obtain the payment of ransom.
Internal ill will can be considered a limited threat but can have theoretically significant effects on the operation of ICSs. The technical capabilities of employees who know how the industrial systems they are responsible for operate can then be exploited for malicious purposes.

Operators must therefore make efforts to comply with legal provisions and best practices in order to secure their office and industrial information systems for sustainable continuity of their business activities. In this respect, protecting and securing industrial systems against cyberthreats are priorities. Faced with the risks identified, ANSSI publishes guides on the cybersecurity of industrial systems. These guides are intended to be pragmatic to support all stakeholders in the industrial world by addressing cybersecurity-related challenges. They offer a simple and appropriate methodology illustrated by real situations: **https://www.ssi.gouv.fr/entreprise/bonnes-pratiques/systemes-industriels/**. The key role of ANSSI is to raise awareness and protect and support its clients in increasing their level of cybersecurity.

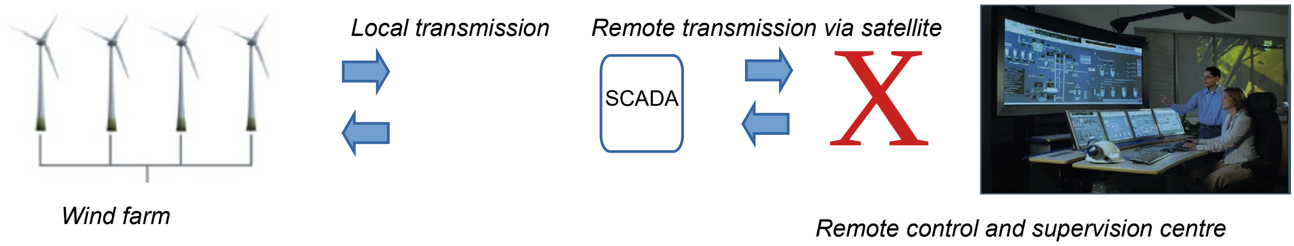
Wind turbines hit by cyberattack
24/02/2022
France

Wind turbine
III will
Communication

THE ACCIDENT AND ITS CONSEQUENCES

A cyberattack originating from a computer virus targeting a satellite resulted in the loss of communication between the remote control and supervision centre of the maintenance personnel and the supervisory control and data acquisition (SCADA) system of numerous wind farms. This attack might have been linked to the start of the war in Ukraine on the same day. Among the many activities using this satellite for communications, 30,000 wind turbines were affected in Europe, including about 50 wind farms in France.

The SCADA manages and processes a large amount of telemetry in real time. It controls technical facilities and alerts operators in the control room through alarms if the physical parameters of the industrial process are out of range. The wind turbines continued to generate electricity and operate in automatic safety mode.



For French wind farms, operators implemented the following mitigating measures:

- daily monitoring visits to farms;
- increased monitoring of weather conditions;
- for certain farms with local wired control, regular transmission of the information collected to the remote control centre of the maintenance personnel.

One wind farm was shut down due to the inability to conduct these visits.

The wind power professional federations and the main operator concerned are conducting an analysis of the risks that could be associated with the loss of satellite communication:

- electrical risk: the delivery station that houses the SCADA has its own means of communication, with the devices enabling monitoring and the transmission of electrical instructions and decoupling orders – it was therefore not impacted;
- environmental risk: values from acoustic and bat mitigation measures are directly integrated into the local control system; only a change in these values by remote supervision would not have been received during the period of loss of communication. Bird detection systems are also directly programmed into the devices or SCADA;
- accident risk: excess speed, fire, loss of integrity – the safety position of wind turbines was unaffected. The devices have local and autonomous control, with safety instrument systems checked annually. In addition, strengthening the safety patrols and monitoring of weather conditions would have made it possible to detect an anomaly that could lead to any of these risks.
- energy independence risk: communications are standardised and secure, and data is encrypted. This was not the target of this cyberattack.

About 10 days later, 4G solutions were implemented, but router sourcing has been delayed and some gaps still exist in coverage. Some operators switched to another satellite. One month after the incident, all wind farms have recovered remote communication. There were no additional incidents resulting from this loss of communication.

THE ORIGIN AND THE CAUSES

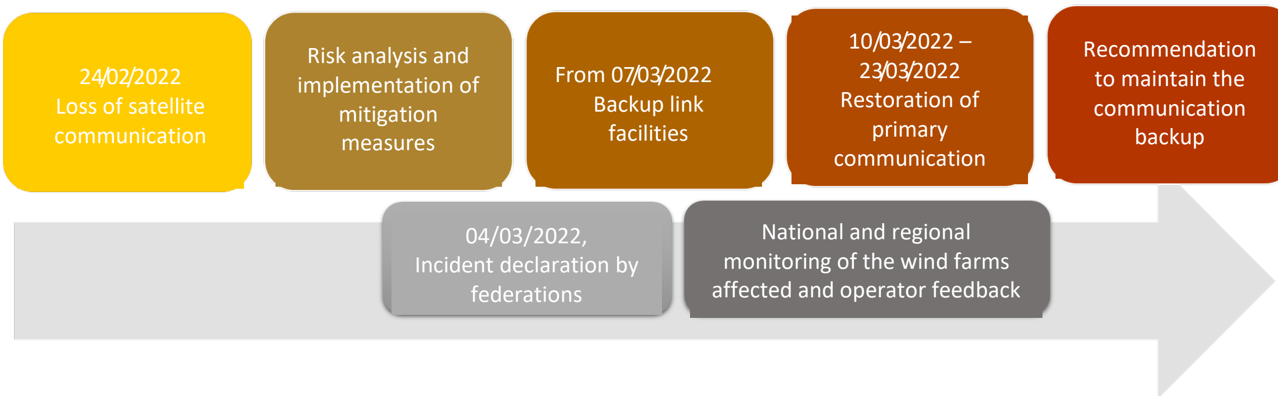
Remote supervision was interrupted due to a virus imported through the satellite link. The receiving modems downloaded the virus from the satellite, damaging the motherboard of the modems. Different manufacturers were affected.

FOLLOW-UP ACTION TAKEN

One week after the start of the incident, the wind energy industry federations and the main operator concerned sent the French General Directorate for Risk Prevention (DGPR) a list of the wind farms affected. As a result, national follow-up was organised to:

- declare the wind farms that were victims of the cyberattack to the relevant Regional Directorates for Environment (DREALs);
- implement mitigating measures;
- check whether there was any loss of capacity of any of the wind turbine safety barriers (i.e. possibility to flag all circumstances: strong winds etc.);
- and, if applicable, declare any additional incidents (blade fall, fire detection etc.) caused by this loss of connection.

The entire inspection chain shared the available information as quickly as possible, particularly thanks to the network of wind power technical advisors present in each DREAL.



LESSONS LEARNED

Communications between wind farms and their remote control centres can take place through 3 solutions:

- the 4G network, although gaps in coverage persist on French territory;
- an ADSL wired network: this solution remains expensive because it is not possible to install the link at the same time as the high-voltage network; also, the telecom operator is no longer opening lines;
- satellite link.

As they cannot control the causes of cyberattacks, operators and maintenance providers wanted to implement sustainable back-up solutions for satellite communication. The 4G modem was the solution that was chosen, despite the gaps in coverage.

Faced with the difficulties in supplying electronic parts (routers, modems), a maintenance operator is considering setting up a larger spare part storage. In this area, supplies of equipment are subject to tension around the world, especially for equipment containing semiconductors.

This event raises the question of the availability of control skills. Remote control is taking precedence over local control provided by operators. This highlights the importance of having robust means of communication between the industrial units being controlled and their remote supervision centres. This mode of operation is increasingly widespread in industrial facilities, including those related to new forms of mobility (hydrogen distribution, stationary storage of batteries etc.) and those that may pose accident risks. In addition, this new remote human-machine interface may lead inspection services to check the operation of these centres in order to ensure that it complies with applicable requirements and, if necessary, improve its regulatory framework.

National coordination by professional federations and the DGPR has made it possible to collect information quickly and provide reassuring and consistent information to competent authorities. This event highlights the necessary upskilling of the various stakeholders in industrial risk, specifically preventing acts of ill will aimed at digital information systems.

It demonstrates and complements the analyses of experience feedback on cyberattacks available on the BARPI website:

- A synthesis on "Industrial cybersecurity";
- Flash "Industrial cybersecurity: Scope and past accidents".

Leak of burning sulphur in a chemical plant

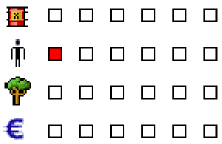
01/07/2021

Meaux (Seine-et-Marne)

France

Hazard
Design
Sulphur

THE ACCIDENT AND ITS CONSEQUENCES



At 5:45 p.m., a leak of burning sulphur occurred at the foot of a heat exchanger located at the outlet of a sulphur combustion furnace in the sulphation workshop of a chemical manufacturing plant. The spread of the product generated a pool fire. The operator triggered its internal emergency plan (IEP) at 6:00 p.m. and called the fire brigade. A safety perimeter was set up, and 4 employees were evacuated. Before the arrival of the fire brigade, employees closed a valve, which stopped the leak. Firefighters set up a water curtain to reduce the release of sulphur dioxide (SO_2). At 8:00 p.m., the fire was extinguished. The emergency services conducted a survey of the building with explosimeters. The operator monitored the reactor temperature.

In total, 750 kg of liquid sulphur spilled. The toxicity analyses performed around the site showed no presence of SO_2 in the ambient air around the site. The extinguishing water was contained on the site. Analyses of this water were performed the following day to determine their treatment methods. The property damage caused the shutdown of the unit's reactors for several months. An employee of the facility (member of the second intervention team) was transported, as a precaution, to Hôpital de Meaux and was discharged a few hours later, as their condition did not cause concern.

Heat exchanger

Rupture of the heat exchanger (view from below)

Sulphur leak from the heat exchanger

Visible material damage outside the workshop

THE ORIGIN AND THE CAUSES

On the day of the incident, at 12 p.m., a loss of connection between the distributed control system (DCS) and pilot valves resulted in shutdown of the workshop. The sulphur supply valve of the furnace closed.

At 2:18 p.m., the DCS detected a mismatch between the command and the expected state of this valve, causing it to reopen. The opening of this control valve for 2 hours (from 2:16 p.m. to 4:38 p.m., the valve having closed through the low temperature interlock device of the furnace), with the furnace stopped, caused an accumulation of sulphur (670 kg) at the bottom of the furnace.

At 5:15 p.m., the decision to restart the workshop was made. When the furnace was restarted, exothermic combustion being higher, the temperature reached in the exchanger at the outlet of the furnace exceeded the design temperature of the exchanger, leading to its rupture.

The two root causes identified concerned the workshop's DCS programming:

- a programming error from the old system when switching to the new DCS in 2007, which required a valve control module to be manually switched during a workshop safe shutdown phase;
- a programming error that required locking the furnace sulphur delivery valve when there was a mismatch (difference between the actual situation and the situation expected by the system) of the combustion inlet valve in the furnace rather than the position (open or closed) of the combustion inlet valve.

FOLLOW-UP ACTION TAKEN

Following this incident, the inspection authorities for classified facilities conducted a reactive facility inspection visit on the same day at 9:45 p.m.

In accordance with the inspection request, the operator submitted:

- information about the disposition of extinguishing water. The analyses performed on this extinguishing water did not reveal any specific pollution. The amount of water recovered was around 400 m^3 and was treated in the on-site wastewater treatment plant;
- incident analysis report;

- positioning on the measurement limit for portable SO_2 analysis devices to decide on exceeding the alert threshold set on an hourly average at 300 µg/m³ for this substance. In conclusion, the operator indicated that the resolution of the devices made it possible to detect a concentration corresponding to the alert threshold of 300 µg/m³.

The operator indicated in its incident report that a thorough analysis of the malfunctions of the DCS was in progress. Because the facility was shut down, a safety review was launched to determine additional countermeasures.

In addition, a study of the sulphur accumulation scenario in the furnace was conducted. The operator planned to work with its design office to assess the impact areas in the scenario, if any, the associated probability and severity, and the adequacy of the safety barriers and risk management measures currently in place. The inspection requested that this scenario be included in the preliminary risk analysis and possibly in the detailed risk analysis of the hazard study no later than the site hazard study review due 18 months after the incident.

LESSONS LEARNED

The distributed control system (DCS) has been changed to correct programming errors.

Two additional safety barriers have been set up before restarting the facility to prevent sulphur accumulation in the furnace from recurring:

- addition of an interlock: shutoff of sulphur loading valves in the furnace when there is low combustion air flow;
- addition of a flow meter to the line delivering sulphur to the furnace with interlock: shutdown of the sulphur pumps on detection of a flow with this new flow meter and a low combustion air flow.

The hazard study will soon include a scenario of sulphur accumulation in the furnace. This scenario will take into account the opening of the sulphur inlet valve during plant shutdown or during low combustion air flow and the possibility of having a leaking valve as a triggering event.

Construction, restart, testing: steps not to be overlooked

Analysis of feedback on industrial incidents/accidents that took place during these stages highlights the importance of organisational and human factors in preventing situations involving deviations. These are often phases that are subject to deadline pressure and in which facilities are not functioning optimally. Operators and their management teams are required to perform actions that are not part of the normal conduct of business. Risk analysis and culture play a key role in preventing situations that could lead to substantial consequences.

1. Organisational and human factors in the construction, restart and testing phases:

The sample studied for this fact sheet consists of events that took place during construction, restart or testing phases since 1 January 2021. Organisational and human factors were highlighted in 55% of incidents and accidents in this sample (33% for all incidents and accidents recorded in the ARIA database in 2021 (inventory source)).

1.1. Key role of risk analysis:

In the sample, 24% of the events with a known or suspected cause show failures in risk analysis as a trigger. The 4 events presented in this fact sheet provide examples. The specific operation of the facilities during these phases is not necessarily studied in its entirety. However, situations not foreseen in the risk analysis may arise during these steps, particularly during restart.

ARIA 57985 – 20/09/2021 – Ars-sur-Formans (Ain) – France

At about 10:45 a.m., as gas supply was being restored to part of the interconnection station, an explosion followed by a gas leak occurred on a portion of pipe. The French Office for Investigation and Analysis of Industrial Risks (BEA-RI) showed that the risks associated with restoring gas supply had not been sufficiently considered. It concluded that there had been an internal explosion of an air/gas mixture.

1.2. Work organisation called into question:

Of the incidents and accidents in the sample, 34% were due to the fragility of the procedures/instructions/guidelines for the construction, restart and testing steps. These were sometimes incomplete or not sufficiently precise for situations that can prove to be unusual. More generally, overall work organisation is important for the smooth running of the steps involving risk. Analysis of the context of the events selected for this fact sheet highlights situations in which the operators found themselves faced with decisions to be made and several actions to be taken at the same time, alone and without management support. Due to inadequate procedures, they were unable to make the right decisions or do the right thing.

1.3. Communication levers:

Poor communication is rarely given as a reason because it is difficult to perceive, but it can lead to situations in which doubts persist and errors are easy to make. For example, if participants in a testing, construction or restart operation do not communicate enough with each other about "who does what", then situations can occur in which no one performs an expected action. If it involves a check before restart that is not performed, a problem situation may not be detected, possibly leading to an incident or accident.

Moreover, for some situations, recurring malfunctions are not sufficiently resolved due to time pressure or management inaction. Operators then develop adaptability practices that serve as "best practices" but are not defined in a procedure.

2. Avoiding contributing factors in accident situations during these steps:

2.1. Strengthen employee involvement:

A hold point before any testing or restart must make it possible to perform a risk analysis and avoid accident situations. It must be included in the procedures or best practices of the operational teams defined after the initial risk studies.

To better understand these steps, the lessons learned from the events presented and the sample studied show overall strengthening of the employee safety culture, particularly through:

- review of the training processes for operator upskilling;
- implementation of procedure audits to uncover "oral best practice" situations and document them;
- improved escalation of weak signals and faults;
- creation of a space for exchanges between operations and maintenance teams (ARIA 59285);
- strengthening the role of supervision.

ARIA 58814 – 25/03/2022 – Mitry-Mory (Seine-et-Marne) – France

Three successive explosions occurred during nitrogen leak tests on steel liquid petroleum gas cylinders intended for containing toxic gases in a workshop of an industrial site. After the accident, the BEA-RI investigation highlighted the fragility of the application of the training process at the site; the operator reviewed the mentor training procedure, revised the training materials and strengthened procedure audits.

2.2. Improve subcontracting management:

Maintenance and work operations usually involve subcontractors. The sample of events studied in the restart, construction and testing phases demonstrates the importance of the involvement of such subcontractors in the analysis of imported and exported risks. The investment of external companies is an essential link to ensure a maximum level of safety. Workers should have the same safety culture as on-site operators to avoid risky situations during and after construction work. For this purpose, it is necessary, based on the lessons learned from the feedback on industrial accidents, to strengthen their training and supervision. In this regard, BARPI published a synthesis concerning subcontracting and risk control in 2019.

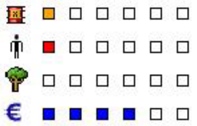
3. Keys to inspection checks

3.1. Check compliance of practices with standards

Some requirements provided for in ministerial or prefectural orders concern organisational and human factors, such as regulatory controls of facilities by operators, procedures/instructions/guidelines and staff training. These points must receive special attention in the inspection when analysing operator accident reports. It is useful to check that practices comply with both the requirements and the procedures established in relation to the requirements. An inspection may request means implemented by the operator to ensure that personnel are aware of the procedures and apply them. The non-compliance record may then require corrective actions to be taken that address the organisational and human factors at the site; this helps prevent incidents and accidents over the longer term.

For the most critical stages, a system of staff certification based on training and competency assessment may exist. The inspection can then check that this system is adequate.

Although a prefectural authorisation order governs the activities of the site during operation, the preliminary construction phase must not be neglected, as it is also sensitive to risks. The "construction site" phase could also be supervised, particularly to strengthen the alert procedures and ensure the availability of fire protection.



ARIA 59164 – 08/06/2022 – Chatelaudren-Plouagat (Côtes-d'Armor) – France

A fire broke out on the logistics platform of a retailer (56,000 m² building), which was empty and under construction. Firefighters had difficulty accessing the nearest water sources: as the platform was not yet in operation, it did not have operational extinguishing equipment. The fire spread quickly, and half of the warehouse surface area was affected in a few hours.

3.2. Comparison of the operator's analysis with feedback on industrial accidents

In addition to the official inspection, the operator's analysis of the event should be compared with the data available in the hazard studies and in the ARIA database. The operator can identify and correct the primary technical causes quickly, but root causes are more difficult to discern, which is why it is worthwhile reminding the operator to refer to existing feedback on experience, both internal and external.

ARIA 59563 – 02/07/2021 – Saint-Fons (Rhône) – France

Discharge of flammable solvents at a chemical site during a reactor devolatilisation operation. This event shows technical focus of accident analyses sent by operators. The technical causes are often well analysed, and enable the occurrence of the event to be understood, but the organisational factors are omitted.

3.3. Find out more

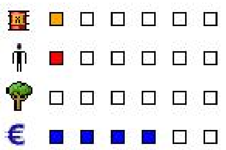
Analysis of the causes of an event is part of a system. An additional step in the search for causes consists in analysing the context in which the event took place. Below, there are examples of contexts to characterise when an incident/accident occurs, some of which have been clearly shown in the accident examples.

Context type		Examples
Institutional context	Regulatory context	regular or irregular situation, ongoing administrative or criminal proceedings
	Economic context	company performance, change of operator, acquisition
	Social context	redundancy plans, strikes, subcontracting
Production/activity context	Load and type of activities	overload or not, new product, launch
	Production	restart, shutdown, works, maintenance, batch etc.
Physical/physiological context, work environment	Weather context	Heatwave, extreme cold, wind
	Physical environment and workstation ergonomics	Noise, brightness, clutter, odours, vibrations, dust, working at height, wearing PPE
	Physiological aspect	night, shift work, recent change
Team context	Type of team	alone, rotating team, small staff
	Seniority in the position	beginner, expert, veteran
	Atmosphere in the work group	motivation, sharing of experience, companionship
Activity analysis		one-off task vs regular task, repetitive work, deadline pressure etc.

Fire in a warehouse under construction
08/06/2022
Chatelaudren-Plouagat (Côtes-d'Armor)
France

Warehouse
Construction
Works
Fire
Difficult intervention

THE ACCIDENT AND ITS CONSEQUENCES



At about 10:30 p.m., a fire broke out on the logistics platform of a retailer (56,000 m² building), which was empty and under construction. The fire spread quickly within 4 of the 8 existing cold stores.

Gas cylinders (particularly propane) that were being used for the work were engulfed in the flames and exploded, forming flaming projectiles: three neighbouring houses were evacuated during the night as a precaution.

Firefighters had difficulty accessing the nearest water sources: as the platform was not yet in operation, it did not have operational extinguishing equipment. The fire spread quickly, and half of the warehouse surface area was affected in a few hours.

The nearby road junction serving the site from the N12 road was closed. Traffic was disrupted for part of the night on the N12 because of smoke. A lower-tier Seveso establishment on the opposite side of the road was put on alert.

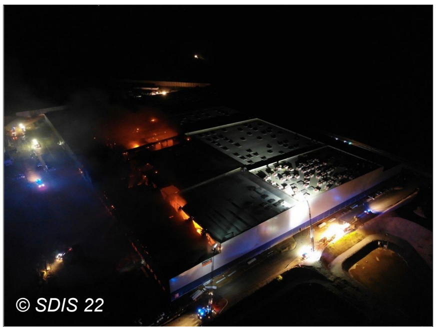
Monitoring was carried out to avoid the fire resuming: a demolition company was commissioned the next day to demolish the affected structures to prevent collapse and reignition.

The extinguishing water either evaporated or was contained on the site within the cold stores. The extinguishing water collection basin had been created but was not yet connected on the day of the accident. As a precaution, the sectional valve of the containment basin was closed. However, no aqueous effluent left the site.

Three firefighters were overcome during the intervention; one of them was placed under observation at the hospital until morning.

Waste was disposed of using appropriate streams (including pumped water): a total of 1,650 metric tons of waste was treated.

The operator estimated the cost of the loss to be €34 million. One hundred and fifty people were laid off temporarily. Commissioning of the platform was delayed by 15 months.



Drone photo

Drone photo 2

THE ORIGIN AND THE CAUSES

The origin of the fire related to concrete floating work (using a double-blade concrete power trowel) in a cold store under construction. The presence of insulation board stored near the thermal float machine explained the rapid development of the fire, which then spread to the structure (timber frame).

The subcontractors were of foreign origin and experienced difficulty making themselves understood when alerting emergency services: the firefighters believed at first that they were responding to "a refrigerator fire" but understood when they arrived on-site that the magnitude of the fire was much greater. Valuable time was thus lost in transporting extinguishing means on the necessary scale.

The prefectural operating permit issued on 9 November 2020 required the presence of 10 fire hydrants supplied by an internal tank with a capacity of more than 1,000 m³ for fire protection: this tank was empty on the day of the accident, however, as the platform had not been commissioned.

The task of the firefighters was complicated by the absence of fire doors, which had not yet been installed, causing concern that the fire might spread to the other half of the building, which was nonetheless separated from the burning part by what was assumed to be a two-hour fire-rated wall.

The firefighters had to use a fire hydrant located more than 300 m away on the opposite side of the road, bringing traffic on the interchange that passes under the road to a standstill. To obtain sufficient resources, 110 firefighters from 19 fire brigades equipped with about 30 fire engines were called to the site.

Missile effects of the gas cylinders caught in the fire (whose number and location were unknown at the time of the intervention) made the intervention of firefighters dangerous.

The warehouse was empty: no other hazardous material was involved in the fire. The items caught in the fire consisted of the insulation board in the cold stores and the wooden frame. The fumes were not considered toxic: the wind helped to disperse them in the opposite direction, away from the town of Chatelaudren-Plouagat located about 1 km away.

The fire was finally brought under control in the morning. Monitoring was carried out for several days to avoid any reignition (smouldering fire that could spread via the insulation board).

FOLLOW-UP ACTION TAKEN

The inspection authorities for classified facilities (DREAL Bretagne - regional directorate for environment) visited the site the next morning, accompanied by DDTM 22 (Departmental Directorate for the Territories and Sea of Côtes-d'Armor). The fire was under control by then. The firefighters were still on-site and maintained their monitoring and continued to hose the debris to prevent reignition. The mayor, *communauté de communes* (federation of municipalities) and representatives of the operator and prime contractor were on-site. Residents displaced in the night had returned home.

Disposal of the extinguishing water was of particular concern because the platform is close to wetlands. DREAL and DDTM made sure that the water was contained on-site.

The environmental consequences were limited. Emergency measures were therefore not required. Post-accident environmental monitoring was not considered necessary (non-toxic fumes and limited duration of the fire).

However, in its visit report, the inspection authority asked the operator to:

- implement on-site monitoring to prevent reignition,
- control access (press and onlookers around the site, which were numerous in the days after the accident),
- monitor the adjacent watercourse and nearby wetlands,
- manage waste using the appropriate streams: many exchanges with the prefecture took place to find outlets for the large quantities of waste generated,
- submit an accident report.

LESSONS LEARNED

What measures are applicable before the operational phase?

- A prefectural operating permit governs activities of a site during operation, but the preliminary construction phase is a sensitive one in terms of risks. Is it necessary for prefectural orders to require monitoring of the "construction site" phase for the procedures for alerting emergency services? Fire protection methods? Methods for containment of extinguishing water? Must these resources be operational even before operations are launched?

Explosion on a nitrogen cylinder filling station
25/03/2022
Mitry-Mory (Seine et Marne)
France

Explosions
Tests
Design
Training
Procedures

THE ACCIDENT AND ITS CONSEQUENCES

On Friday 25 March 2022 at 9:22 a.m., three successive explosions occurred during nitrogen leak tests on steel cylinders intended for containing toxic gases in the cylinder maintenance workshop (AEB) of an industrial site specialised in the production, packaging and delivery of special gases.

The operator shut off the nitrogen and helium supplies and triggered the confinement alarm and internal emergency plan (IEP). Sixty-eight people were confined until 10:30 a.m. Production resumed on the rest of the site. The operator checked the electrical and heating facilities of the area impacted. A service provider covered 2 m² of the damaged roof with sheeting.

Four people were slightly injured, 2 of whom were taken to the hospital by firefighters. Three people are on sick leave for psychological shock and ear pain. The financial consequences are estimated to be between €80K and €100K for material repairs.

The explosions were due to overpressure during the inflation phase of the test, resulting in the bursting of the steel cylinders. The operator in charge of the test connected 4 low-pressure cylinders (LP, 22 bar) to the high-pressure cylinder filling system (HP, 200 bar) for the nitrogen leak test. After a few minutes of pressure increase, 3 cylinders exploded and a fourth deformed.

Normal (left) and deformed LP cylinders after leak test (right)

LP cylinders after the accident

THE ORIGIN AND THE CAUSES

The origin and causes of this accident are as follows:

- Operator under training in a position requiring certification (he did not have knowledge of the operating mode and was trained only in the HP filling system);
- Absence of trainer/manager in the week of the accident (aggravating factor);
- Low frequency of steel LP cylinders passing through the leak test station (first since early 2022);
- Design error in the high-pressure cylinder filling system: cylinders for the LP filling system could be connected to the HP system. The keying system was ineffective. The cylinder positioning area is divided into small cells whose width must prevent the placement of LP cylinders wider than a "standard" steel cylinder. However, the small steel cylinders (14 L) could be positioned;
- Absence of a visual message prohibiting LP cylinders on the HP cylinder filling system;
- The existing procedure specified the prohibition of connecting the steel cylinders to the HP filling system but was not clear about the pressure to choose to perform the test.
- Risk not identified in accident risk analysis.

FOLLOW-UP ACTION TAKEN

Following this accident, the inspection authorities for classified facilities conducted an inspection of the facilities on 29 March 2022. The French Office for Investigation and Analysis of Industrial Risks (BEA-RI) is opening an investigation. The BEA-RI technical investigators visited the site three times to gather all the information and testimonies necessary for the investigation.

The inspection authorities for classified facilities requested from the operator:

- an action plan that includes the measures taken or planned to avoid recurrence of a similar accident;
- to complete its safety instructions and/or its internal organisation plan to manage the expected behaviour of employees, some of whom went to the accident site after the first explosion;
- to set up certifications for cylinder handling workstations after validation of acquired knowledge;
- to ensure that operating procedures concerning at-risk functions are known, adapted and understood by authorised personnel;
- that no LP cylinder can be placed on the HP bench before the HP bench is brought back into service.

The BEA-RI investigation report[1] concluded in particular that there is a need to re-examine the training and certification of operators, improve the ergonomics of the leak test bench (display of the cylinders that can be tested and the pressures to reach, separation of the bench from the rest of the workshop by fencing, keying device etc.), set up a clear and accessible system for monitoring authorisations, coupled with a procedure that does not allow unauthorised and unaccompanied operators to be registered in the work programme, investigate the root causes of tensions in the AEB team and implement the necessary measures to regain an atmosphere of collective awareness.

LESSONS LEARNED

The main actions taken by the operator after the accident are as follows:

- Investigation of the possibility of working only with "standard" cylinders (test pressure of 350 bar). In other words, investigate the possibility of eliminating steel cylinders;
- Reminders and verification of the application of the site certification procedure;
- Review of the mentor training methodology;
- Review of support documents concerning certification and training (implementation and monitoring: mentoring sheets, authorisation cards etc.);
- Strengthening of the implementation of procedure audits;
- Update of the single document;
- Update of the accident risk analysis;
- Review of the design of the cylinder filling system: include more efficient keying systems;
- General lessons: illustration of the fragility of the on-site training process.

[1] BEA report: https://www.igedd.developpement-durable.gouv.fr/IMG/pdf/rapport_airliquide_vdiff_cle5d1469.pdf

Discharge of flammable solvents at a chemical site

02/07/2021

Saint-Fons (Rhône)

France

Chemical engineering manufacture
Design
Restart
Procedures
Communication

THE ACCIDENT AND ITS CONSEQUENCES

The event took place in a workshop of a chemical plant at the start of a devolatilisation operation on a reactor when the process was being restarted after a period of shutdown of the facility for maintenance.

The devolatilisation operation consists in removing the light products (xylene, isopropanol) by evacuation and heating the reactor. The volatile products are then recovered in a volatile container and pumped to another workshop.

Xylene

H226: flammable liquids and vapour
H332: harmful if inhaled

Isopropanol

H225: highly flammable liquid and vapour
H319: causes serious eye irritation
H336: may cause drowsiness or dizziness

A pressure detector on the line for sending volatile products to the other workshop shuts down the pump used to draw off the volatile products from the container and closes the valves located upstream and downstream of the container. These actions prevent the pump from idling and the product from flowing back from the workshop downstream.

An anomaly in the pressure build-up phase of the pump generates fluctuations in pressure and causes recurrent triggering of the detector whenever the pump is started up. This anomaly was known but not communicated or corrected. Out of habit and experience, the technicians regularly clear this safety alert to continue the devolatilisation operation.

In the incident, the pressure detector triggered the closure of two valves (1 upstream and 1 downstream) right from the start of the process, at about 3:30 a.m. The technician was busy with another task and did not immediately clear the anomaly. The volatile container and the collection container continued to fill up. The vacuum unit was still running when the detector near the non-condensable recovery container upstream of the volatile container reached its high level and triggered the closure of the valve upstream of the vacuum pump. The reactor was still being heated and continued to produce volatiles that could no longer be evacuated.

At 4:40 a.m., one hour after first safety alert associated with the pressure detector had been triggered, the technician cleared the safety alert linked to the pressure detector associated with the transfer pump for sending the contents of the volatile container to the second workshop; this enabled the opening of the valve between the non-condensable container and the volatile container, as well as the valve downstream of the volatile container. However, the reactor could still not be emptied because the valve upstream of the vacuum unit remained closed.

The pressure and temperature of the devolatilisation increased. A leak was detected at a flange on the exhaust gas duct.

At 8:15 a.m., the technicians in the control room (about 6 to 8 people) decided, in the absence of a procedure, to stop heating and inject nitrogen into the reactor. However, the split-range system on the nitrogen line (set based on the pressure measurement in the reactor) closed the nitrogen inlet in the reactor (upon a high pressure measurement in the reactor) and opened the bleed valve for the vapour phase of the reactor to be sent to the vent outside the building.

Two employees were overcome by the solvent vapours and received care by the site's firefighters. The operator estimated the amount of solvent spread on the ground under the flange that leaked at the time of the event to be 5 litres. The amount of solvent vapour discharged at the purge vent has not been estimated.

THE ORIGIN AND THE CAUSES

The operator identified the "process" causes that led to the discharge, specifically:

- A safety action on a pressure detector that was not necessary in the start-up phase, which triggered the closure of valves upstream and downstream of the volatile container when the pump started;
- cascading closures of valves resulting from the isolation of the volatile container and leading to isolating the reactor;
- the split-range control system, which prevented the injection of nitrogen into the reactor in the event of increased pressure in the reactor.

However, the operator did not formally identify organisational factors as "causes" in its accident analysis. They did also play a role in the occurrence of the event, however:

- a process with recurrent malfunctions without reporting the information to the engineering teams, specifically a safety action that was triggered inappropriately at each start-up phase and that needed to be cleared quickly;

- undocumented process control adaptations: clearing a safety action at each start-up phase was known to the technicians but not documented;
- absence of a safety procedure for the facility. Faced with an increase in temperature and pressure in the reactor, the team chose to stop heating and inject nitrogen. It was found that stopping the heating would have been sufficient and that nitrogen injection was not possible under these conditions. Instead, it caused the product to be discharged outside through the vent.

FOLLOW-UP ACTION TAKEN

Following the analysis of the accident, the operator established the following technical measures:

- 30-second inhibition delay on the safety mechanism associated with the pressure detector downstream of the pump for sending volatile products to the other workshop;
- modification of the safety actions on the pressure detector by removing the closure of the valve upstream of the volatile container;
- modification of the safety actions upon detection of the high level in the non-condensable container:
    - stopping heating of the devolatilisation reactor by closing the vapour inlet valve in the system around the reactor;
    - installation of nitrogen supply to the reactor by opening the nitrogen injection valve.

The inspection authority noted that nitrogen injection was the cause of the discharge of solvent vapour to the outside. The operator was asked to justify this measure to avoid venting the vapour phase in the reactor in the event of excessively high pressure due to the split-range control system.

The description of the event indicated a leak from a flange at the end of the event, but no cause was analysed and no associated preventive or corrective measure taken. Additional information was requested from the operator to complete its analysis of the event concerning this leak.

Finally, the operator did not offer any proposals for measures related to organisational failures. The inspection authority requested that it provide the measures planned for improving the tracking and reporting of anomalies observed by the teams on the ground, as well as those that help the technicians to make decisions, particularly regarding the conduct of processes that do not have procedures. In addition, the lack of follow-up of the corrective measures implemented indicated a lack of experience feedback buy-in by the operator.

LESSONS LEARNED

This event showed the technical focus of the accident analyses sent by the operators. The technical causes are often well analysed and can explain the occurrence of the event, but organisational factors that also played a role in the occurrence of the event are omitted, as in this case. These partial analyses led to the proposal of partial corrective measures that did not prevent organisational dysfunctions.

Among these organisational causes, we note the partitioning between the teams on the ground that must manage the process and the engineering teams in charge of designing the process. The practice evidenced in this event is an adjustment to anomalies by the teams on the ground, without reporting the malfunctions to the engineering teams.

Another common organisational factor that emerged from this event concerns an oral culture at the expense of procedures. This event showed the limitations of this system: without a management procedure for degraded situations and without simulation exercises, the decision that was made under stressful circumstances was incorrect when the temperature and pressure in the reactor increased. Similarly, the absence of a formal safety action clearance instruction related to the pressure detector made it impossible for the technician to prioritise this task among others.

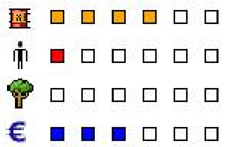
This event also drew attention to the operator's level of accident analysis and the lessons learned. The exhaustive analysis did not take into account some elements and information: organisational causes, the causes of the leak at the flange, and comparison by the operator of the event with the scenarios in the hazard study. The main measure implemented at the end of this event was a process modification that was not subject to ex-post assessment.

Finally, the criteria for reporting events to authorities will be the subject of a specific inspection as the operator did not deem it necessary to provide the authorities with information about the occurrence of this event.

Explosion of a natural gas transport pipeline at an interconnection facility
21/09/2021
Ars-sur-Formans (Ain)
France

Piping
Restart
Works
Explosion

THE ACCIDENT AND ITS CONSEQUENCES



At about 10:45 a.m., as gas supply was being restored after work to replace a part of the interconnection station, an explosion followed by a gas leak occurred on a portion of the aboveground system fed by a pipeline (diameter: 609 mm; maximum service pressure: 80 bar).

While a team consisting of about 10 people (service providers and the operator) was finishing testing operations, with pressure stabilised at around 20 bar, a particularly violent explosion occurred, rupturing a DN600 pipe and destroying part of the system. The personnel were evacuated and the facilities shut off upstream and downstream. Emergency services established a safety perimeter of about 500 m, while traffic on the departmental road was cut off at the nearest roundabouts. The emergency response plan was triggered.

The explosion caused the rupture and scattering of fragments of equipment of various sizes (up to about 3 t for the upstream part of the expansion loop) over distances of up to 530 m (fragment of the upstream expansion loop). The pipes located in or near the extension were displaced, equipment was torn off, and supports were damaged or shifted. Two technicians were injured (perforated eardrum and dislocated finger caused by a fall). The damage was initially estimated to be several million euros. More than 80,000 m³ of natural gas was released into the atmosphere. The event did not result in any immediate impact on gas transport or delivery, however, because of the grid coverage of the area. Media impact was limited, as the facility is located in an agricultural area.

THE ORIGIN AND THE CAUSES

Several factors led to the situation:

- gas supply is normally restored very gradually, but on the day of the accident it was sudden, as the pressure increased very quickly to about 20 bar;
- the Châtillon-sur-Chalaronne block valve station is located about 15 km upstream of the interconnection. It was from this station that restoration of gas began. However, it does not have a pressure indicator, making it more difficult to ensure the gradual pressure increase required in the operating procedure. The technician at this station was guided remotely by telephone to open the valve that was not a throttle valve;
- the operating procedure used covered the entire work phase, from emptying to gas restoration. The procedure offered little detail (one line in the corresponding table), with no further analysis;
- restoration of gas in the Ars system was complex, given the possibility of air pockets.

Gas restoration operations must allow air pockets to be evacuated at the time of filling. According to the national operating procedure, two methods are possible: saturation or purge. A local analysis is also recommended depending on the actual configuration of the system and the available hardware. During preparation of the Ars intervention, the local operating procedure specified a hybrid process mixing purge and saturation (3 increments of 2 bar), which does not strictly correspond to those recommended in the national operating procedure. In addition, there was no supervision to advise or assist the teams in conducting these very common phases, which are nonetheless challenging in this type of complex system.

For natural gas, the flammable range increases sharply with pressure: at 21.5 bar, the known standard range of 5% to 15% increases to 5% to 27%, and the ignition energy is lower. The personnel were unaware of this. The pressure values set out in the national procedure for the increments (2 to 3 times 2 bar) are low and adjusted to an internal explosion risk related to ignition of the gas/air mixture (pressure reaching up to 15 to 20 times the initial pressure). Even in this case, the pipe will resist because it was designed for a higher testing pressure. The team saw the pressure risk as being associated rather with a burst than with a potential internal explosion. During the manoeuvre, the pressure reached 20 bar, which was not within the desired limits; however, they did not believe this posed substantial risks.

The gas carrier thoroughly investigated the accident because of the significant material damage and operating losses, as well as the impact on the teams. In conjunction with the French Office for Investigation and Analysis of Industrial Risks (BEA-RI) and DREAL (regional directorate for environment), they focused on the following:

- integrity of the equipment and systems still operational on the site. This concerned the other processing facilities and regulations on the site, as well as the components that ensure tightness at the interfaces of these facilities, and the DN600 pipe (bent at 90°), including in its underground extension. This point was an important part of the emergency order issued by the prefect of Ain;
- inventory, location and storage of the damaged or even fragmented equipment, pending expert assessment;
- metallurgical assessment of certain parts: the gas carrier used 3D scanning to visualise the displacements and reconstruct on the map the condition of the systems after the accident;
- chemical analyses of residues collected from the interior of the damaged or displaced pipes: soot thus helped to locate the starting point of the explosion;
- analyses of the condition of various pieces of equipment: instrumentation, particularly valves and alignment of systems, to establish the condition of the system at the time of the explosion;
- understanding of the conduct of operations and the choices made during preparation.

Investigations of the components related to the explosion were also extensive.

However, regarding energy input, the actual cause has not been fully established. Scenarios involving electrical sources (sparks during normal operation or heating, ATEX equipment, stray currents), electrostatic sources (friction, dust etc.), projectile impacts (flying debris), electromagnetic waves, chemical decomposition (gases or other traces) and pyrophoric dust have been studied. At this stage, the most likely energy input appears to involve dust (pyrophoric or through electrostatic discharge). Note that expert assessments are still underway in March 2023 as the period of stability one hour before the explosion remains unexplained.

The explosion mechanism is also the subject of detailed modelling, but appears to have resulted from rapid flame propagation until detonation. In this configuration, the pressure reached could have been multiplied by 15 or 20, depending on the configurations of the systems. The initial pressure was much higher (21.5 bar) than that expected in this phase (6 bar maximum): pressure during the explosion may have reached 320 bar, a value much higher than the testing pressure, which would explain the damage observed.

FOLLOW-UP ACTION TAKEN

In addition to the gas carrier, the company's social and economic committee and BEA-RI, supported by INERIS (National Institute for Environmental Technology and Hazards) and DREAL, conducted investigations and inspections after the accident. The inspection authority conducted 3 visits: one on the day of the accident, after which an order for emergency measures was issued by the prefect of Ain, and the other two focusing on the "integrity of the facilities still in operation" and "procedures for gas restoration".

The gas carrier prepared an accident report, which was submitted to DREAL and BEA-RI on a regularly updated document platform. BEA-RI will publish its report once the investigations have concluded.

Technically, the equipment was dismantled and part of it was sent to the carrier's analytical laboratory, while part was stored on-site if needed for further assessments.

A notice was issued concerning the reconstruction of the system with improvements based on feedback on industrial accidents. Equipment from the previous system was reconditioned after expert assessment and reused. The work is planned for 2023 for a return to service at the end of the year. The cost of the reconstruction amounts to about €8 million euros, not including the costs of the study and expert assessments.

LESSONS LEARNED

The feedback from this event has been extensive, even without knowing all the causes. From the start, DREAL has been tracking the feedback, and further exchange is planned for May 2023. The gas carrier presented the event through the Gesip[1] feedback study group and to AFG[2]. BEA-RI published a feedback sheet without waiting for the publication of its report. In light of the event, it is regrettable that the feedback from the accident in Cerville in 2014, involving similar phenomena, was not the subject of such consultation with the operators concerned.

Following this analysis, the gas carrier implemented the following experience feedback:

- procedures have been updated and are more explicit;
- for some operations, an advisor provides an outside perspective, and a review of the instructions has been organised;
- an awareness kit has been developed for personnel, and the importance of pressure in explosion risks is now highlighted;
- strict observance of the procedures is required during pressure build-up;
- other approaches are also recommended: perform separate gas restorations instead of grouping them in a single operation, for example.

[1] Groupe d'Etude de Sécurité et des Industries Pétrolières (Oil and Chemical Industry Safety Research Group)

[2] Association Française du Gaz (French Gas Association)

Environmental monitoring and decomposition of products in fumes

During fires, the composition of the fumes and their possible impacts on the environment and the health of residents are major concerns. The latest major fires have demonstrated the need to better characterise emissions, particularly atmospheric emissions in the event of a fire loss, for substances that can induce accidental toxicity effects as well as those that can cause chronic effects. In response, various regulatory and technical measures have been taken. These actions are described below.

1. Initial environmental samples

After the Rouen fire in September 2019, a series of changes were made to strengthen regulations concerning prevention and preparedness for accident management. Among the various measures taken, the regulatory changes made to the decree of 26 May 2014 and 11 April 2017 aim to improve the characterisation of the substances likely to be emitted in a major fire and to manage the initial environmental sampling. Specifically, the measures are as follows:

- The operators of classified facilities subject to authorisation storing combustible materials (warehouses) and Seveso establishments must indicate, in hazard studies, the main products or substances likely to be generated during a fire. This also applies to decomposition products from buildings (roofing, insulation, cables) and containers, such as drums. This obligation applies to new and updated hazard studies conducted after 1 January 2023 or, for upper-tier Seveso establishments, at the review of the hazard study and no later than 30 June 2025.
- The Internal Operation Plan or internal defence plan of these establishments must include provisions that ensure the availability of equipment and personnel required for the proper conduct of the initial environmental sampling in the event of an accident concerning the pollutants defined in advance after study. These provisions may involve knowledge sharing or the use of private service providers.

The purpose of the initial environmental sampling is to provide the first indications of the chemical signatures of emissions and the initial facts for estimating their potential impacts. These initial environmental samples are intended, first, to confirm the relevance of the measures taken to protect people, and second, to provide facts about the event to the public. These initial environmental samples will also make it possible to support, if necessary, the steps taken subsequently as part of post-accident management of environmental and health impacts.

The opinion of 1 December 2022 on the implementation of initial environmental sampling in accidents involving facilities classified for the protection of the environment clarifies these regulatory provisions.

Beyond this regulatory component, the French General Directorate for Risk Prevention (DGPR), with the support of the French National Institute for Environmental Technology and Hazards (INERIS), has started work to deploy mobile means of analysis and sampling (MoMAP). This system aims to implement, for facilities not subject to the regulatory obligation, the initial environmental sampling in the event of a major fire loss and will provide elements that contribute to the characterisation of the substances emitted to determine their potential impact.

The proposed system consists of equipment set up with operators acting on behalf of the government. Three levels of intervention are offered in the system to provide a flexible response based on the intensity and duration of the industrial accident.

2. INERIS Omega-16 guide

This guide has been updated to reflect the regulatory changes mentioned above. In particular, although the previous version of the guide focused on emissions of products with accidental toxicity, such as carbon and nitrogen oxides and acid gases, the new version of includes products that cause chronic toxicity, such as polycyclic aromatic hydrocarbons and dioxins. These changes provide technical elements both for the prior identification of compounds likely to be emitted by various fuels at the hazard study stage, including, if applicable, contributions attributable to storage conditions and locations (containers, buildings etc.) for the prioritisation of substances to consider for the measurements to be taken in the event of a real fire loss.

For the assessment of pollutant emissions, the Omega-16 guide includes a bibliographic section, a theoretical study and the synthesis of specific tests performed. The bibliographic section made it possible to identify the main gaps in the available data and major influencing factors and determine accordingly the content of the experimental campaign conducted by INERIS. This experimental campaign, which is unique for the diversity of measurements taken, thus made it possible to complete the data available for various substances and provide orders of magnitude of emission factors grouped in a table in the appendix of the guide and accessible online. The tests focused specifically on a dozen basic products, such as wood or plastics, as well as manufactured products, such as batteries and computer equipment. It should be stressed that, while the guide provides quantified values, they should be considered as orders of magnitude, the emission factors of polluting substances being highly dependent on the fire conditions and, particularly, the presence of underfloor ventilation. Despite the diversity of tests performed, there remain many products for which data are not available. For these products, the theoretical part makes it possible to make an initial estimate of the emissions to consider based on the chemical nature of the fuel, mainly for products inducing accidental toxicity and, to a lesser extent, those inducing chronic toxicity.

Note that these changes have been made in operational tools for the INERIS emergency situation support unit (Casu), particularly the source term component. The modelling of the dispersion of the plume and possible particle fallout on the ground is then performed using tools that have been integrated into an ergonomic interface specific to use in emergency situations.

3. Professional methodological guides

Regulatory texts provide that professional methodological guides recognised by the ministry in charge of classified facilities may be developed.

Three guides for the chemical and petroleum, storage and logistics, and hazardous waste industries have been recognised or are under development.

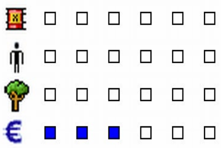
The purpose of these guides is to assist operators in:

- identifying consistent product categories in terms of composition and fire behaviour, including container and building types;
- for each category, determining the types (or families) of decomposition products likely to be emitted;
- prioritising the types of decomposition products to identify the substances to assay for (possible markers) and determining the appropriate sampling methods.

Each professional guide offers a methodology adapted to the specific characteristics of its industry, taking into account the typology of the products or waste likely to be involved and the management of the business.

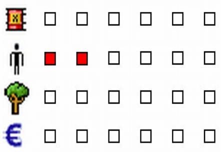
These three guides, as well as the guide developed by INERIS, break down the expectations and offer tools to determine the type of sampling to perform and the practicalities, facilitating the implementation of the entire system.

4. Initial feedback



ARIA 58596 – 02/02/2022 – Joué-sur-Erdre (Loire-Atlantique) – France.

During a fire at a plastics plant, the Regional Directorate for the Environment, Development and Housing (DREAL) of Pays de la Loire implemented a detection kit. This testing was conducted jointly with the departmental firefighting and emergency response service (SDIS 44), and made it possible to perform a toxicological analysis of the fumes starting at the outbreak of the fire, as well as the set-up of air sampling canisters. The sensors made it possible in a second step to determine the safeguard measures to implement for the environment (authorisation of consumption of plants and animal production).



ARIA 55537 – 15/05/2020 – Venice – Italy

In the morning, a fire broke out on the premises of a chemical plant after an explosion. A large plume of black smoke was visible for kilometres. Residents were advised to remain in their homes and, for those closest to the plant, to place damp towels around their closed windows. A hundred firefighters worked to contain the flames. At 2:00 p.m., the city sirens sounded to signal the return to normal. Two employees sustained serious burns.

5. Conclusion

The feedback on industrial accidents, particularly the fire of September 2019, led to an effort to improve emergency management and quickly acquire the factual elements on the composition of fumes to inform the public.

The purpose of all the measures currently being deployed, both within the framework of the regulatory component and as part of the public system, is to be able to conduct the initial environmental sampling as soon as possible. This rapid activation of the already organised and planned systems should save valuable time when deploying them and thus obtaining the initial details.

Feedback on future fire losses will make it possible to test the tools and help to fully roll them out.

Fire in a plant specialising in processing recycled elastomer waste

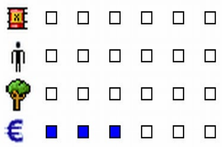
02/02/2022

Joué-sur-Erdre (Loire-Atlantique)

France

Vulcanisation
Fire
Oil
Storage

THE ACCIDENT AND ITS CONSEQUENCES



At around 8:00 a.m., a fire broke out in a 2,500 m² building housing the rubber vulcanisation line in a plant specialising in processing recycled elastomer waste. Just after starting his shift, an employee noticed an orange glow from the vulcanisation line. Noting that the heater on the vulcanising press had caught fire, he triggered the fire alarm and alerted the emergency services. The retention pond for collecting firefighting water was isolated. The fire spread to the storage racks to the left of the building and the stock of finished products (1,000 m³ of butyl and latex plastics and wooden pallets) located outside. A large plume of black smoke, visible for several kilometres, spread over agricultural and uninhabited areas. The personnel were evacuated, and inhabitants were asked to stay indoors. The fire brigade arrived at around 8:30 a.m. and was able to bring the fire under control despite difficulties in obtaining a water supply, with the fire continuing in the outside storage area until 1:30 p.m.

Safety patrols during the night made it possible to identify several fire outbreaks and bring them under control. Heavy equipment was used to spread out the fire residues. Outbreaks of fires occurred regularly over 3 days after the initial outbreak. The firefighters declared the end of the intervention after 5 days. Eight tanker trucks emptied part of the retention pond, i.e. 256 m³. The operator initiated regular rounds to monitor the pond.

The vulcanisation line remained out of operation for 10 months. A 10 t travelling crane was destroyed, as well as part of the structure and the entire roof and cladding of the vulcanisation line. A part of the roof of the building next to the latex and butyl lines and the partition between the two buildings were also destroyed. Among the resulting damage, the press reported that a machine worth €2.5 M had been destroyed inside the building.

THE ORIGIN AND THE CAUSES

Hose crimp ring

The fire started in the rear of the vulcanising press' oil heater. This recent machine had been installed at the site by its manufacturer and had undergone regular maintenance. This heater was designed to heat vulcanisation moulds to 180°C. The incident was caused by a rupture of a hose containing the heated oil inside the heater.

In addition, the slope at the heater caused the burning oil to escape from the building and prevented the fire from spreading to nearby machines but not to the storages of external combustible materials.

FOLLOW-UP ACTION TAKEN

During the fire, air quality measurements were conducted over a wider perimeter around the site by firefighters specialised in technological hazards, and the results were reassuring. These measurements concerned substances with acute toxicity. Air samples were also taken at several locations under the smoke plume to analyse other pollutants. Firefighters in partnership with DREAL and the air quality monitoring association Air Pays de la Loire positioned the canisters. The pollutants assayed have been defined based on the INERIS Omega-16 guide, which lists toxic substances that may be emitted by fires. Air Pays de la Loire asked the TERA Environnement laboratory to analyse the samples and screen for more than 50 majority gaseous species, also targeting BTEX (benzene, toluene, ethylbenzene and xylene) and chlorinated volatile organic compounds. The results of the samples confirmed the results of initial measurements conducted on the day of the fire. The concentrations found throughout the site, at the STC property limit and in the hamlets downwind, were well below the toxicological benchmark values.

Grass samples under the plume of smoke were taken the day after the loss in accordance with the prefectural decree on emergency measures. They were supplemented by milk analyses: 2 series of sampling several days apart on 3 farms. The results do not show any impact of atmospheric fallout from the fire. Indeed, the three milk samples comply with the maximum levels authorised by the European Union. In addition, there was no significant differences between grasses exposed to smoke-related atmospheric fallout and those not exposed.

LESSONS LEARNED

The operator took the following measures:

- raising awareness of the risks and consequences of fires and continued first-aid training for staff;
- in sensitive areas, increase in the number of islands with storage areas for finished products and raw materials using concrete blocks, as required;
- update of the single document with a fresh look at fire hazard assessment;
- implementation of an incident register to identify recurring problems that may result in a fire loss;
- limitation of the spread of fire between buildings, possibly by installing a firewall;
- identification of equipment posing a risk and their placement in a protective enclosure;
- installation of detection and autonomous extinguishing means near equipment at risk;
- provision of sufficient water capacity for firefighter intervention.

As part of the process of administrative regularisation of the site, a hazard study must be conducted to size the water requirements, determine the impact areas in the event of fire losses and review the storage conditions.

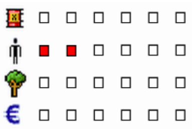
For the public authorities, this incident made it possible to test the regional system after the Rouen accident in 2019. The action consists in providing the fire and rescue services with canisters through an agreement with the regional air quality monitoring association.

There were lessons learned concerning coordination between the various stakeholders in this type of situation. This made it possible to define the procedures identifying several operational situations mobilising different means as well as "communication" actions.

Fire in a chemical plant
15/05/2020
Venezia
Italy

Chemical
Maintenance

THE ACCIDENT AND ITS CONSEQUENCES



The establishment is in an industrial area which is a national chemical and petrochemical hub with a high concentration of major accident establishments. There are vulnerable territorial/environmental elements within a two-kilometer radius of the site (buildings, airport, port and lagoon). The establishment produces specialized chemicals used in the following sectors: cleaning, fine chemicals, paper, plastics, textiles, cosmetics, colorants.

The accident occurred in the morning during modification works, consisting in the connection of a tank containing wastewater with flammable substances, as xylene, acetone, methyl acetate, ethanol, ethylbenzene, o-xylene and hexyl acid (amount directly involved was 130 tonnes), to the wastewater network. The event consisted of an explosion of the tank and subsequent fire, involving systems and equipment pertaining to the other plants, in a succession of fire and explosions (internal domino effect).

The damages include: 2 employees sustained burns to 30-40%, hospitalised for 2 months, but at the end they recovered well; 3 employees with first degree burns to the face and neck, inhalation of toxic fumes, multiple bruises: they recovered in a couple of weeks; all production areas (entire plant units, tanker trucks, fiberglass tank, IBC drums and drums on the forecourt), as well as part of the laboratory building, the control room adjacent to the production units and the cooling tower area; €35,000,000 (material losses) plus €14,000,000 (response, clean-up, restoration costs).

As regards the effects on the environment resulting from the washout of the extinguishing water used during the event, no pollutants were detected in the protected lagoon nearby, while traces were found in the industrial canals of the site.

THE ORIGINE AND THE CAUSES

The accident occurred as a result of modification interventions by a third company, which was modifying a connection between the wastewater network and a tank. One hour before the event, these workers had cut the pipe that was being worked on. The event occurred when the cut pipe was being sealed: the use of an electric arc welder caused the flammable mixture within the tank (wastewater vapour) to ignite. The tank on which the line modification work was to be carried out was blanketed with nitrogen pumped in through the same pipe that was cut and then welded. It is possible that, precisely as a result of cutting the pipe, the inert nitrogen atmosphere was lost due to the broken connection.
In addition to the possible human cause, elements concerning the organizational causes are:

- hazardous substances stored on the forecourt were not adequately protected by fire prevention systems;
- no evidence of risk analyses having been done on the modification works carried out;
- inadequate isolation of equipment and not correct connection system between pipe and tank;
- maintenance/repair activities not subject to the SMS management of change procedure;
- lack of clarity on the implementation of the PTW (Permit To Work) system;
- lack of control of on-site activities and related formalization;
- inadequate training of the operators of the third company on the hazards related to the change.

FOLLOW-UP ACTION TAKEN

At the time of the event (approximately. 10:20 a.m.), the Internal Emergency Plan (IEP) was activated by the shift emergency coordinator (shift attendant) and external emergency services were alerted in the form of a call to the local station of the fire brigade. About on-site systems, automatic fire protection systems and fire-fighting equipment were activated, consisting in tank cooling towers and fixed water monitors serving the installations. About 22 people, belonging to internal and third-party staff, who were present at the establishment on that day were evacuated.

The External Emergency Plan (EEP) was activated by the Prefects Office, following first notification from the fire brigade. Following intervention by the off-site external emergency services, the fire was brought under control at 2:00 p.m., and the emergency was declared over at 5:00 p.m. Approximately 30 fire brigade vehicles attended with 90 firefighters, including from neighbouring stations. In implementation of the EEP, people living in the industrial district within 1 km radius of the establishment were asked to stay at home with the windows closed until the emergency was over.

After the event, the following emergency and environmental safety operations were carried out:

- a contract was concluded with a company specialising in making sites environmentally safe, resulting in a plan being issued;
- all tanks were completely emptied and the site was made safe by removing all hazardous substances present at the establishment;
- the environmental status was continuously monitored during decommissioning activities (hazardous substances possibly present in the air); cleaning of underground utilities, remediation and refurbishment of collection and sewage systems.

LESSONS LEARNED

About lessons learned and results of experience, it is important to pay attention to the following:

- Conduct a risk analysis on all changes (preliminary risks, risks during implementation and risks during operation), resulting in the identification of preventive and protective measures to be implemented, as well as the related training activities for the staff.
- Always keep systems subject to modification works under isolated and inert conditions to prevent the environmental conditions from changing, which could lead to the formation of potentially flammable and/or explosive atmospheres.
- The work permit process must always pay attention to: checks prior to and/or during the performance of the activities; supervision by the persons responsible; formalization.
- Follow the procedures for the correct positioning of stores of hazardous substances and mixtures on the forecourt (e.g. tanks, drums, IBCs, etc.), including related fire protection systems and equipment, as a result of an appropriate risk analysis.

In chemical specialties industry, there are many SMEs with a poorer safety culture. The lack/impoverishment of safety culture makes internal organization impervious to external knowledge: the industrial associations should supply the weakness of single enterprise, with a capillary action to disseminate knowledge through their network.

Regulatory authorities have a huge responsibility. In particular, the mandatory inspections, required by the Seveso Directive, should verify actual safety culture. Inspectors should pay attention to the management of changes, where recognized good practices may be forgotten, preferring informal procedures, which may cause accidents with flammable substances. Sample interviews with personnel of all levels can be useful for inspectors to understand the level of awareness and knowledge of the personnel. Inspectors should finally prescribe specific interventions for the promotion of the safety culture.

Incompatible products/mixtures: how to prevent them ?

Incompatible products and mixtures have many causes and require the development of many measures to prevent and control them. As shown in the film, preventive and protective measures are possible both in terms of regulated safety (procedures, ergonomics, material solutions) and managed safety (training, experience sharing). The management of incompatible products and mixtures must be based on a safety culture that emphasises asking questions when analysing potential accident situations. This requires analysis of incidents and accident scenarios that have occurred in other sectors. This topic, which brings the 2023 seminar to a close, often applies to events in the waste sector and during maintenance operations.

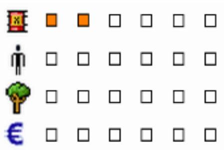
1. Identifying incompatible product and mixture types

The sample studied for this topic consists of the events that took place since 1 January 2017 and are listed in the ARIA database. There were 169 events involving incompatible mixtures. The mean during this period is consistent, numbering 25 to 30 events per year. All sectors are concerned, which demonstrates the importance of fully understanding the essential safety principles of labelling, proper storage and reduction of the sources of mixtures.

1.1. The various types of mixtures and incompatibilities:

People tend to limit the notion of incompatible mixtures to acid/base mixtures. This incompatibility is the best-known and most widely studied. However, the ARIA database lists other types of incompatible mixtures, including content/container reactions, product reactions with water or moisture, and acid/acid mixtures.

Incompatibilities also concern situations related to the states of products (gas/solid or solid/solid interaction). This makes their control all the more complex.



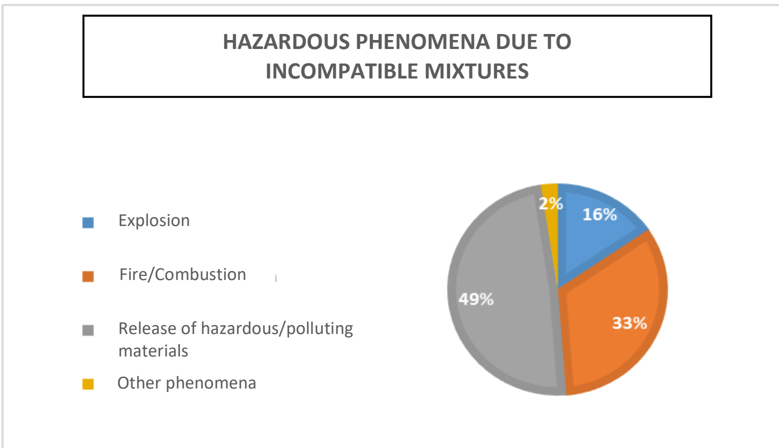
ARIA 57413 – 01/06/2021 – Le Pont-de-Claix (Isère) – France

During a bleach manufacturing operation, a chlorine leak was detected in the chlorine supply line of a chemical platform workshop. During a maintenance operation, a flange was replaced with a different material, titanium, which was inappropriate for dry chlorine. The leak occurred 4 hours after the equipment was restarted after the maintenance operation.

Keep in mind that the availability of safety data sheets (SDSs) and the identification of all the chemicals and their incompatibilities offer two solutions for risk mitigation when there are incompatible mixtures.

1.2. The consequences:

The reactions of incompatible mixtures can result in various phenomena, such as discharges of hazardous materials and exothermic or explosive reactions. Data from the ARIA database illustrates these consequences and their likelihoods.



Incompatible mixtures are a source of factors that worsen accident situations. In 11% of the cases, the incompatible mixture worsened the accident phenomenon and caused a domino effect in 4% of the events studied.

2. Measures to reduce risk:

Analysis of the events presented shows the need to develop mixed risk mitigation measures that combine technical, human and organisational barriers. The safety management system at Seveso establishments as well as the body of procedures in other industries make it possible to determine the most effective combinations of risk mitigation measures. The organisation set up by the operator must guarantee the reliability of the barriers put in place.

2.1. Monitor and ensure the operation of the barriers

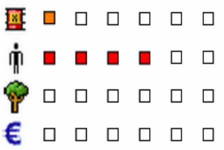
Material defects account for 25% of the problems that cause incompatible mixtures, while human action accounts for 50%. Thus, the implementation of regular monitoring and review of equipment and procedures makes it possible to reduce the occurrence of unwanted events. Operators can develop actions based on the following steps:

- identification of barriers;
- management of technical barriers (procurement, installation, care and maintenance);
- optimisation of organisational barriers (training, procedures, definition of roles);
- ensuring reliability of barriers through organisational measures and review of procedures;
- consideration of feedback on industrial accidents.

2.2. Developing a safety culture through experience sharing

Operator knowledge of technical safety barriers makes it possible to improve risk mitigation. This first level of safety must be combined with the development of the competencies of technicians, particularly the inclusion of human factors and the development of critical thinking in all situations. Risk mitigation, regardless of the situation (normal or degraded operating conditions or 10-year maintenance), requires regular reassessment of the knowledge acquired by technicians about processes. Operational safety analysis and experience sharing are needed to organise operations with a maximum level of safety.

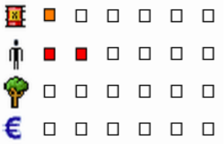
Two phases are particularly exposed to these risks: stripping and cleaning. The major accident discussed here provides a significant illustration.



ARIA 59018 – 12-05-2022 – Slovenia – Kocevje

The explosion occurred during a transfer of diethylenetriamine, contained in a road tanker, to an on-site storage tank not intended to receive this substance because it contains epichlorohydrin. In the plant, 5 workers (1 employee, the truck driver and 3 subcontractors) were killed and 25 employees were injured, 1 of them seriously. In the following weeks, 2 other workers (1 employee and 1 subcontractor) died at the hospital. The 150 firefighters, members of Slovenian army and employees brought the fire under control at about noon and the intervention was completed at about 22:00. Local authorities asked residents not to leave their homes and to close their windows out of concern about toxic fumes.

BARPI also calls attention to cleaning phases, particularly when it involves a product storage change. These phases must be subject to increased caution to reduce the risks of mixing with residual effluents or mixing in containments. This type of event comprises 20% of accidental mixing situations recorded in the ARIA database. Several assumptions can be made about these accidents. First, the cleaning/rinsing phases were largely unacknowledged and unstructured. This led to a decrease in watchfulness when performing this type of operation. In addition, lack of knowledge of the hazards concerning certain mixtures, particularly acid/acid, made it impossible to identify these high-risk situations.



ARIA 49704 – 23/05/2017 – Le Grand-Quevilly (Seine-Maritime) – France

When the accident occurred, the technician was draining and cleaning part of the facilities. The tanker's tank used to pump nitric acid was made of carbon steel without antacid coating and was therefore not compatible with nitric acid. Nitric acid attacked and pierced the bottom of the tank, generating nitrogen oxide vapours.

Toxic fumes in a food processing plant

06/04/2020

Villefranche-sur-Saône (Rhône)

France

Agrifood industry
Toxic mixture
Emergency Unit

THE ACCIDENT AND ITS CONSEQUENCES

In 2020, during a period of confinement due to the COVID-19 pandemic, in the "acid" room of a food processing plant, 600 L of concentrated sulphuric acid 96% was mistakenly transferred into a storage tank containing 1,250 L of nitric acid 30%. A yellowish then reddish cloud resulting from the formation of nitrogen dioxide was released by the reaction of the sulphuric acid with diluted nitric acid. The 70 employees were evacuated. Firefighters were alerted and intervened. A 300-m safety perimeter was established. The neighbouring street was closed from 3 p.m. on the same day until the next day at 6:00 p.m. As a precaution, a shopping mall was evacuated and residents were asked to stay indoors. Firefighters installed two water curtains, and the tank was hosed to cool it. Emptying and removing the tank took 2 weeks.

THE ORIGIN AND THE CAUSES

Several human errors caused the accident. A maintenance technician had ordered the acid in place of the storekeeper who was on sick leave. Due to difficulties finding the correct reference, the technician had ordered sulphuric acid instead of nitric acid after calling the supplier. In addition, the transfer of the acid was generally handled by the storekeeper but was carried out in this case by an apprentice who was aware of chemical hazards but had little experience (experience of only one acid transfer). The apprentice was assisted by a colleague from the maintenance department, who provided support outside the room but had no specific training in this type of operation. The procedure did not specify the type of acid to be transferred. There was no notice in the room, and the tank only indicated that it contained an acid.

FOLLOW-UP ACTION TAKEN

The operator took the following measures:

- posting of notices in the room on the retention and on the outer tank;
- incorporation of product reference checks into the procedure, as well as measures to be taken in the event of an emergency;
- automation of the product reference check before transfer;
- identification of the storekeeper's duties and responsibilities and training required for each duty;
- improved training of technicians in transfers, chemicals and update of the procedure;
- designation of the people responsible for acid transfer: the storekeeper and 2 technicians; display of the list of people authorised to enter the room on the door of the room.

LESSONS LEARNED

Analysis of this event reiterated the following principles:

- specific skills must be properly managed to avoid business interruption;
- hardware and software ergonomics must be reviewed when processes are changed;
- all changes must be identified and analysed and include the training needed for their proper adoption and use;
- procedures must be explicit and operational and complement the skills developed and maintained by the personnel.

The management of a facility requires ongoing collaboration between all the stakeholders (managers, supervisors, technicians, inspectors, partners) to reduce confirmation bias. By developing a safety culture based on sharing experience and analysing our practices, we will ensure a better level of safety and production.

Chlorine leak from a chemical platform

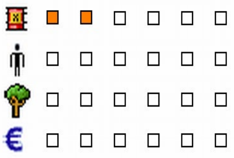
01/06/2021

Pont-de-Claix (Isère)

France

Chemical engineering manufacture
Chlorine
Choice of materials
Training

THE ACCIDENT AND ITS CONSEQUENCES



The incident took place in the chlorine compression workshop of a chemicals manufacturing plant on a chemical platform near Grenoble. The plant specialises in the manufacture of isocyanates used in paints and varnishes.

The role of the chlorine compression workshop is to purify the chlorine coming from the electrolysis cells where it is produced. It is then distributed either as a liquid for customers outside the site or as a gas for the various users of the platform after evaporation of the liquid chlorine.

At about 8:00 p.m., during a bleach manufacturing operation, a chlorine leak was detected in the chlorine supply line of the bleach workshop. Chlorine detection safety devices shut down the workshops and chlorine supply, which stopped the leak. The building's water curtains and backup sanitation were activated.


Operational water curtain

At 8:05 p.m., the operator triggered the gas alert and activated its internal emergency plan. Fifty people were instructed to lock down. The firefighters read values of 7 ppm and 10 ppm leeward near the building. The values behind the water curtains were zero. Three technicians using self-breathing apparatus found the origin of the leak on a joint, on a flange on the line feeding the bleach section.

At 12:30 a.m., the internal emergency plan and gas alert were lifted after negative readings inside the building and near the leak.

THE ORIGIN AND THE CAUSES

The leak occurred on a restriction orifice, which is a device that physically limits the flow in a pipe.

During a maintenance operation, this restriction orifice was replaced with a titanium material that was inappropriate for dry chlorine. The leak occurred 4 hours after the equipment was restarted after the maintenance operation. The titanium part was completely corroded by chlorine gas.

The specifications did not specify the material to use. In addition, the maintenance personnel in charge of the modification were not aware of the titanium/dry chlorine incompatibility.

FOLLOW-UP ACTION TAKEN

After the event, the operator took the following corrective and preventive actions:

- improvement in the initial and continuous training of employees in the content of the corrosion guide, in each workshop;
- creation of an internal and external experience feedback sheet (Eurochlore) related to product/material incompatibility;
- organisational structural change to ensure that the personnel are familiar with the site piping specification;
- modification of the change request process to include a point concerning material/product compatibility.

LESSONS LEARNED

The lack or loss of knowledge related to incompatibilities between products and materials underscored two important lessons:

- training of employees and refreshers in each workshop concerning the risk of corrosion related to product/material interactions. Knowledge of process line specifications in each sector must be improved;
- organisation of the site for accessibility to the manufacturer's documentation, and data standardisation. This point was identified as a root cause.

The inspection authority noted the fast response of the operator to this event, which took place outside working hours, with the triggering of all safety actions and the lockdown of personnel in 5 minutes. Thus, no chlorine leaks were released into the environment outside the site, and no one was harmed.

Explosion in a chemical factory

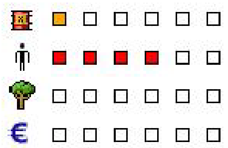
12/05/2022

Kočevje

Slovenia

Explosions
Tanker truck
Pipe coupling

THE ACCIDENT AND ITS CONSEQUENCES



At approximately 8:00 a.m. on May 12, 2022, a truck arrived with a trailer and so-called ISO container to the freight entrance from the Roška cesta side to the company reception. The receptionist accepted the transport documents and entered them into prescribed records, returned them to the driver, carried out the entry weighing of the truck and completed the entry formalities at approximately 08:07 a.m. The transport documents and records later showed that the driver brought approximately 19,550 kg of liquid raw material diethylenetriamine (DETA) in an ISO container. The driver knew the way to the tank transfer station at the plant. He arrived at the transfer station at 08:12 a.m. The driver drove along the internal transport route, then to the transfer station, and stopped at its end in front of the epichlorohydrin (EPI) transfer station for deliveries to the C2 storage tank. The driver handed over the transport documents to the operator of the transfer station present there, and began preparations for streaming.

Between 08:12 a.m. and 08:21 a.m., the driver and operator performed the connection of the flexible pipes for the liquid and gaseous phases between the container and the fittings of the EPI transfer station, the connection of the grounding. The operator then started the streaming operation on the computer terminal in the kiosk, and at 08:21 a.m. turned on the pump P C2.1 for streaming on the transfer station. The operator stopped the flow after 2 minutes so that he could take a sample of the raw material into a sample bottle, then continued the flow and took the sample to the laboratory of the Smole II plant for the employees there to take it to the analysis laboratory at the Klas building. The operator then returned to the transfer station. The driver was waiting in the cab of the truck, and the operator was waiting in the kiosk next to the streaming station. During preparations and streaming, five people who are not related to streaming and had no influence on it crossed the transfer station area.

At 08:37 a.m., a physical explosion first occurred, in which the lower part of the C2 tank blew up. There was a release of substances, which in the form of an eruption of a cloud of vapors covered a wider area of the transfer station. The C2 tank collapsed, followed after approximately 0.5 seconds by the ignition of a vapor cloud lasting approximately 0.3 seconds; and the formation of a fireball that rose and pulled the surrounding air along the ground. At the same time, projectiles of equipment parts (pipes, valves, structural sheet of the tank, etc.) were created, with a reach inside and outside the plant area. The fireball burned and rose for about 5 to 7 seconds, its diameter and maximum height were over 200 m. Released hazardous substances were burning on the transfer station and at the site of the C2 tank with thick black smoke that was clearly visible from the surrounding area. Secondary fires also broke out in the tank storage area and next to the Smole II plant, which also engulfed one of the fans on the roof of the cooling water system facility, the resin homogenization plant, IBC containers next to the Smole II plant, and so called electrical room on the west side of Smole II plant. Other dangerous substances were also involved in the secondary fire.

An examination of the area of the incident later showed that the driver, the operator and three employees of the subcontractor were dead immediately. One person employed by the contractor died in the following days, and another employee died approximately four weeks after the incident, both at Ljubljana hospital. All died as a result of exposure to the fire.

THE ORIGINE AND THE CAUSES

The company was founded in 1954 and today employs around 200 workers. It is organized as a joint-stock company, divided into three business units (BU), namely BU Chemical Industry, BU Wood Industry and BU Footwear Industry. The company products are used in the paper, construction, rubber, wood processing, footwear, textile and paint and varnish industries.

The company complies with the national Decree on the prevention of major accidents and mitigation of their consequences. In accordance with Environmental Protection Act and the Regulation, the company has obtained an environmental protection permit for the operation of the plant and prepared a safety report as well as a protection and rescue plan.

The cause of the explosion was streaming of DETA into the tank with EPI, as the decisive assumption for ensuring safety - that the ISO container with EPI will be equipped with a TODO coupling - was wrong. The operator explained that initially it was planned for the supplier to provide a container for EPI with a special connection, but this was not realized later. For the streaming of EPI, the operator intended to use a TODO coupling, which would only be compatible with the connector on the ISO container containing the EPI. However, it turned out that the use of TODO couplings is not suitable, because all ISO containers (regardless of the substance in them) are made with a "EURO" connector, to which the TODO coupling cannot be connected due to the thread on the ISO container.

Therefore, an interim modification was carried out in the plant, and as a final decision they made the use of a Kamlock type D connector on the flexible pipe for EPI, but due to the danger associated with changing the chemical, they did not check whether the measures were adequate. The operator equipped only the flexible EPI pumping hose with the Kamlock coupling. On the day of the accident, a flexible pipe equipped with a Kamlock coupling was used, which was an established practice for streaming of EPI after the plant found that the TODO coupling could not be used due to incompatibility with the ISO container. However, when using an adapter, the Kamlock coupling can be connected to any ISO container, also to an ISO container containing DETA.

On the day of the accident, the driver of the truck with the ISO container drove in front of the EPI storage tank instead of in front of the DETA storage tank, and the warehouse worker, regardless of the fact that the name of the chemical DETA was stated on the transport documentation (DETA was also stated on the container), went to the technologist and foreman's office to get the EPI flow coupling and performed a container streaming into the EPI storage tank which led to the accident.

FOLLOW-UP ACTION TAKEN

Immediately after the first explosion, the personnel of the Smole II plant evacuated, which lasted approximately 30 seconds to 2 minutes. At 08:44 a.m., the first intervention firefighting units arrived at the place, and at 08:48 a.m., another 14 volunteer firefighting units were activated. The quick intervention of fire brigades, units of the Slovenian army and employees limited secondary fires/hotspots and prevented the failure of other tanks in the tank warehouse and the spread of fires (some tanks were damaged). It was established that the stable fire-cooling system of the transfer station was disabled in the first explosion. The fires were contained at approximately 11 a.m., the intervention was completed at 9:47 p.m.

According to Environmental Agency data, the explosion did not cause any environmental damage. According to the Mobile Unit of Ecological laboratory analysis, there were no toxic substances in the smoke. After the accident, measurements of substances in soil and water were carried out. There was no impact of the explosion on the ground, the impact on water was small, but National Institute for Public Health advised as a preventive measure not to use of drinking water from several water captures, which was canceled three weeks later.

At the plant, all damaged tanks in sector C were replaced and removed. The plant has reduced production on four lines in Smole plant. Synthesis does not take place on the reaction line where EPI was used. The plant decided not to use EPI anymore for the production of resins.

Additional organizational measures were implemented to prevent potential similar accidents, namely mandatory identification of all incoming raw materials before streaming into tanks and coding of the pumping connection (mandatory confirmation by 3 persons - in addition to the storekeeper and the quality department).

Due to the substantive complexity of the accident investigation, the Ministry for the environment and spatial planning established a working group with the task of analyzing the causes that led to the accident and preparing recommendations for ensuring effective risk management in the plant and other environmental risk plants. The working group consists from representatives of various institutions and inspections services. The working group has not yet completed its work (mandate is till end of March 2023).

LESSONS LEARNED

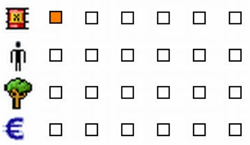
The plant has already introduced new organizational and technical measures to prevent mistakes in the streaming of dangerous substances. In the plant, more emphasis is placed on technical solutions, as this reduces the probability - the possibility of human mistakes. They plan to move the production of EPI resins to a new location, and in this way also reduce the possibility of major accidents. After the accident, the company proceeded to review and amend the Safety Management System and both implementation documents, amend the safety report and the protection and rescue plan, as well as information for the public. The main change of the safety report is the abolition of storage at the site of the plant (storage in barrels in the Hazardous Substances Storage and storage in a tank in the Tank Storage) and the use of EPI in synthesis on the R-7 reactor line. EPI was the substance involved in the major accident. In accordance with the regulations, the operator must review the safety report and if necessary, amend or supplement it within six months from the date of the occurrence of a major accident.

Explosion of a sulphonitric acid tank
03/09/2021
Bergerac (Dordogne)
France

Maintenance accident

Incompatible mixtures

THE ACCIDENT AND ITS CONSEQUENCES



On Friday 3 September at 11:20 p.m., the personnel heard the sound of an explosion coming from the acid storage area. The technicians went to the site and observed the emission of whitish fumes above the tank and the absence of acid spreading in the retention basin. As soon as the gas emissions were detected, the internal emergency plan was triggered. The operator called the outside emergency services. The firefighters and the "chemical risks" unit went to the site. Water curtains (water shields) were deployed at about 1:30 a.m. around the retention system to limit the dispersion of the toxic cloud. The site's containment basin was activated to collect the water used by the curtains. At about 3:30 a.m., the operator decided to drain the tank and transfer its contents to the neighbouring tanks. Once the tank was emptied at about 10:10 a.m., foam (water + foam concentrate) was added through the opening formed by the tear in order to suppress the emission of fumes from the tank. The incident was closed the next day at 12:15 p.m. with the departure of the firefighters.

THE ORIGIN AND THE CAUSES

The cause of the accident was incompatibility between the resin applied to the inner wall of the tank and the sulphonitric acid mixture, which led to an exothermic reaction and to the formation of an explosive atmosphere containing NO2, O2 and VOC. This protective coating had been applied to extend the life of the tanks.

In May 2021, the operator had a protective coating made of polymerised resin applied to the tank concerned. Visual defects, such as blistering, peeling of the resin and roughness at the shell/dome welding were noted upon delivery of this work. The operator decided to carry out a second application operation in agreement with the subcontractor; this took place in July 2021 and proved to be successful. The tank remained empty until 3 September when it was returned to service and the explosion occurred.

The BEA-RI investigation found that the service provider had chosen an inappropriate resin, that the resin manufacturer had not approved the choice of resin, and that there had been no prior testing of the compatibility between the resin and sulphonitric acid.

FOLLOW-UP ACTION TAKEN

DREAL (regional directorate for environment) suggested:

- measures to improve monitoring, through the installation of pressure/temperature sensors in the tanks;
- implementation of methods to detect a loss of containment without spreading in the retention system;
- a study aimed at optimising tank emptying (transfer from one tank to another, or to unfilled backup space);
- measures to manage accident situations, such as the provision of fixed or mobile facilities for foam production, sufficient foam concentrate reserves and electrochemical measuring devices for toxic fumes, especially sulphuric acid for which colorimetric gas detection tubes are difficult to use.

A technical investigation was conducted by BEA-RI (French Office for Investigation and Analysis of Industrial Risks) with the support of INERIS (National Institute for Environmental Technology and Hazards).

LESSONS LEARNED

This accident was the subject of a report by BEA-RI, which proposed measures for the operator and the service provider that applied the resin.

For the operator, BEA-RI suggested:

- provide the possibility of transferring the contents of one tank directly to another empty tank in the acid storage area or to unfilled backup space;
- ensure there is a sufficient amount of acid-compatible foam concentrate to spread foam over the acid to eliminate toxic nitrous fumes;
- perform tests before the implementation of a new product or technique to check that new processes do not generate hazards.

The BEA-RI suggested that the provider should:

- review the process for validating information between stakeholders before product installation;
- increase the reliability of the resin application method to ensure that the result is smooth;
- develop a resin application quality control procedure.

Tank after the explosion

Emergency actions

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.

The graphic charter:

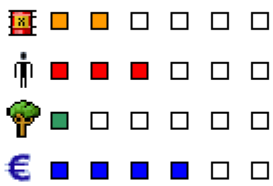
The graphic charter adopted for the presentation of the 4 indices is as follows:

Dangerous materials released

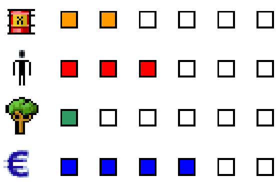
Human and social consequences

Environmental consequences

Economic consequences



When the indices are yet explained elsewhere in the text, a simplified presentation, without the wordings, can be used:



The parameters of the European scale:

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

TECHNOLOGICAL ACCIDENTS ON LINE

For the past 20 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.

The search engine of the ARIA website, in both its French and English version, allows to consult all the summaries of these events and to meet the expectations of Internet users, making BARPI the "Interactive reference media library specialised in industrial accident studies".

Users can access:

- nearly 58,500 events 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 1,800 events plus a wide range of publications!

ARIA
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www.aria.developpement-durable.gouv.fr

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

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DICOM-DGPR/DIV/18122 - Février 2019