Lessons learnt from industrial accidents

Seminar in Paris - France

3-4 June 2009

Final Project Report

2009-01

European Union Network for
the Implementation and Enforcement
of Environmental Law

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 EU Member States, acceding and candidate countries of the European Union and EEA countries. The association is registered in Belgium and its legal seat is in Bruxelles, 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. Projects within the IMPEL annual programme are co-financed by the European Commission.

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 6th Environment Action Programme 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

Lessons learnt from industrial accidents Seminar in Paris – France - 3-4June 2009	Report number: 2009/01
Project Manager/Authors Jérôme GOELLNER –Head of the Department for technological risks **Project Group Members** **Denis DUMONT – Gérard CARTAILLAC- Adèle HEUDIER** French Ministry for Sustainable Development / General department of risks prevention / Department for technological risks / Bureau for Analysis of Industrial Risks and Pollution (BARPI)	Report adopted at IMPEL General Assembly Meeting Córdoba 15-16 April 2010 Number of pages Introductory pages: 4 Report: 112 Annexes: 73

Executive Summary

The collection of the accidents and their analysis is necessary in order to prevent new accidents from occurring again. As a consequence, it is necessary for inspectors to have illustrations of accidents situations, in order to understand what happened actually and what measures were finally taken in such situations. During the meeting, each presentation is carried out by an inspector concerned by the accident - technical description of the accident, the effects, the measures taken, the systems or material that failed, the organisational aspects and particularly the lessons learnt from the accident. The different levels of the accidents are investigated and presented, technical but also judicial or organizational approaches may be carried out.

A glance on the regulations in force is also possible. So, the interest is the share of experience with a high number of inspectors. Apart from the presentations, time is left for exchanges of points of view. The aim is the enrichment of the knowledge for the participants based both on the discussions and the presentations.

The last meeting took place on 3-4 June, 2009 in Paris (France): 19 countries involved, including France – registration of 270 persons including 44 participants coming from EU countries apart from France including Turkey and Croatia - presentations of 21 recent accidents.

Various kinds of recent accidents concerning different fields were presented : e.g. 3 accidents in refineries, major release of oil in a tank farm in Ambes in 2007 in France, major mercury release in Belgium in 2008, blaze at an ethylene pipeline and a nearby acrylonitrile tank in Germany in 2008, fire and explosion of ammonia synthesis gas in 2006 in the UK, transboundary pollution in Latvia, leakage of a hydrogen-pipeline in the Netherlands …

A few topics were emphasized during the seminar: ageing of industrial facilities, communicating under difficult circumstances, accidents with transboundary effects, domino effects, gas distribution pipelines, effects of water pollution by hydrocarbons ...

A report of the 2009 conference in French and English (paper version and CD Rom) includes the different presentations, speeches and some short analysis about transversal issues.

European Union Network for the Implementation and Enforcement of Environmental Law

Agenda of IMPEL conference 2009

Lessons learnt from industrial accidents

3-4 June, 2009

1. Petit Couronne accident - 18/07/2007 - France– DREAL Haute Normandie
2. Limay accident (78) - 31/07/2007 - France- DRIRE Ile de France
3. Köln accident - 17/03/2008 – Germany - Köln district government
4. Binnenmaas accident - 12/10/2007 – Netherlands - Dutch Ministry of environment
5. Vivier-au-Court accident - 15/05/ - France2006 - DREAL Champagne-Ardennes
6. Billingham accident - 06/01/2006 - United Kingdom - The Health and Safety Executive
7. Chateau-Arnoux-Saint-Auban accident - 14/02/2008 – France - DREAL Provence Alpes Côte d'Azur
8. Noisy-le-Sec accident - 22/12/2007 – France - DRIRE Ile-de-France and BSEI
9. Accident in Germany - 16/08/2006 - State Institute for Environment of Baden-Württemberg
10. Antwerp accident - 16/09/2008 - Belgium - Dutch Ministry of environment
11. Saint-Hilaire-sur-Puiseaux accident - 19/08/2008 – France - DRIRE Centre
12. Ambes accident - 12/01/2007 – France - DRIRE Aquitaine
13. Donges accident - 16/03/2008 – France - DREAL Pays de la Loire
14. Linz accidents - 13/08/2003 and 09/08/2004 - Austria - Municipal authorities of the state capital Linz
15. Renaison accident - 30/07/2007 – France - DDSV Loire
16. Anderlecht accident - 22/01/2008 – Belgium - Brussels Institute for Management of the Environment
17. Frankfurt am Main accident - 05/10/2007 – Germany - Regional council of Hesse
18. Accident in Belarus and Latvia - 23/03/2007 - Latvia Coast Guard Service
19. Sillamäe accident - 12/09/2008 - Estonia - Estonian Environmental Inspectorate
20. Saint-Germain-Laprade accident - 01/11/2008 – France - DRIRE Auvergne
21. Laneuveville-Devant-Nancy accident - 20/12/2007 – France - DRIRE Lorraine

LESSONS LEARNT
from industrial accidents

IMPEL Seminar

Paris, 3 and 4 June 2009

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Welcome address to seminar participants

Bernard DOROSZCZUK

Director of the Paris Region's Directorate for Industry, Research and the Environment (DRIRE)

Ladies and Gentlemen,

In my capacity as Director of the Paris Region's Directorate for Industry, Research and the Environment (or DRIRE), it is with immense pleasure and honour that I greet you today here in Paris for this seminar devoted to a strategic reflection and forum on industrial accidents, hosted by France's Ministry of Ecology, Energy, Sustainable Development and Town and Country Planning, along with special participation of the Lyon-based BARPI unit (Bureau for the Analysis of Industrial Risks and Pollution).

The success enjoyed at previous gatherings has inspired you to once again choose Paris and its Region as the venue for sharing your experiences in industrial risk management, a decision may I add that gives me great satisfaction.

This event has now been organised for the 8th time within the framework of the IMPEL network (representing "the union for the application and respect of environmental rights"). The mission of this entity, created in 1992, is not limited to promoting information exchanges and comparing experiences, but extends to encouraging the adoption of a consistent approach encompassing implementation, application and ensuring compliance with environmental rights.

I would like to welcome all members of the industrial installation inspection community working in European Union countries participating in this action network. I see this morning that many countries are represented: Germany, Austria, Belgium, Portugal, Sweden, Latvia, the Czech Republic, Slovakia, Estonia, Turkey, United Kingdom and the Netherlands. Rest assured, I am not overlooking the contingent of French inspectors assigned to supervise the nation's classified facilities and workplace conditions. This broad international attendance is bound to enhance the quality of our exchanges and discussions.

You are assembled here in Paris, within a dense urban environment and far from any high-risk installation. Yet, are you aware that we're actually sitting less than 2,000 metres from the old Grenelle Gunpowder Factory, which over 200 years ago was the site of one of history's worst industrial disasters?

On August 31, 1794 at 7:15 am, between 30 and 150 tonnes of gunpowder, depending on which source you read, exploded in the munitions stockpile at the *Château de Grenelle*, near the Military School in the same district. Trees were felled and buildings collapsed. The noise generated by the explosion could be heard as far away as Fontainebleau. The disaster caused more than 1,000 deaths.

During this troubled period, no one noticed the alarms sounded by the site operator, who beforehand had even alerted the Public Safety Committee that a sudden increase in output posed a major hazard. The report filed subsequent to the disaster, which no doubt had to be taken seriously by the IMPEL network set up at the time, stipulated a number of measures that no matter where you're from 200 years later still seem as pertinent as ever, i.e.:

- Product quality control,
- Reduction of stored quantities,
- Stockpile placed far from residential zones.

To avoid the recurrence of such disasters, feedback is fundamental to the risk prevention process and receives heavy emphasis during seminars like ours.

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In 2008, 1,469 events were catalogued by BARPI nationwide, including 100 in the Paris Region (Ile-de-France). Depending on information available, an evaluation of Paris Region accidents yields the following major trends:

- 61% of accidents resulted in the outbreak of fire;

- 47% of accidents caused the release of hazardous materials or pollutants;

- 10% of accidents produced an explosion.

One accident caused a fatality. 16% of these accidents gave rise to injury, 60% to internal property damage, 64% to operating losses, 9% to surface water pollution, 8% to atmospheric pollution, and 4% to soil pollution. Moreover, 29% of the accidents required evacuating local residents.

Regarding the decrease in occurrence rates for both incidents and accidents, inspection authorities have requested facility operators to systematically identify practical measures for mitigating risks at their source in addition to implementing the best risk control practices. Considerable investment has been made over the past several years by operators to improve site safety; moreover, inspectors have undertaken major efforts to verify *in situ* the level of confidence in the risk control measures adopted and in the organisational features introduced to enhance control over the risk management process.

With nearly 3,000 installations requiring authorization, of which 92 lie within the scope of the *'SEVESO'* directive on hazardous facilities, along with 31 potentially high-risk silos and some 400 storage warehouses, the Paris Region requires very close risk monitoring. Depots containing inflammable liquids located in closer suburban communities with high urban densities and the tens of industrial transport sites occupying over 20,000 m² of floor area in the outskirts further from the capital are cause for concern to local area public officials.

One originality in France is that a key to administering the "upper tier" *SEVESO* sites consists of introducing Technological Risk Prevention Plans (PPRT), which allow affecting both future **and** past urbanisation patterns at the periphery of the 37 Paris Region sites placed in this category. Preliminary risk analyses have led to drafting such plans for around half the sites, with the calendar calling for completing plans for all sites by the end of this year. Our focus has been fully devoted to this task, since experience instructs us just how critical it is to control urbanisation as part of any risk reduction effort at the source.

Given that industrial risk prevention actions must not be confined to '*SEVESO*' classified facilities, the Paris DRIRE Directorate undertook, in 2008, an unexpected control campaign, targeting approximately 25% of the region's warehouses. This large-scale operation exposed a number of serious deficiencies with respect to current fire safety rules.

The level of non-compliance observed during inspection visits was deemed to be significantly inadequate to a point where for 29 of the 64 facilities examined, inspectors proposed that the local Prefect issue a formal order for the site operator to remedy the noncompliant recordings (including provision of fire-fighter accessibility, repairs to fire doors, activation of fire detection systems, response to observations noted by inspection authorities, and verification of water supply facilities and their accessibility).

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As a concluding point, I would like to highlight a first for this 2009 gathering that I feel to be of particular value. Previous seminars have presented a range of accidents related to either the storage or use of hazardous substances found exclusively at industrial installations. For the first time, you'll be informed of an accident involving the distribution of hazardous materials by pipeline, namely a gaseous combustible.

Let's recall that regarding pipes and pipeline facilities, the Paris Region by far contains the highest density of networks throughout all of France, thus making its population the most heavily exposed. Occupying just 2% of the nation's territory, this region concentrates 13 million inhabitants and over 10% of France's total transport and heat network by pipeline.

It is a known fact that more than 800 municipalities in the region are concerned by the crossing of at least one gas or hydrocarbon pipeline, meaning that this eventual risk affects ten times the number of municipalities as the upper-tier '*SEVESO*' installations (and those municipalities having adopted PPRT plans). Furthermore, 10% of the region's population, or 1 million inhabitants, reside less than 100 metres from a transport network of this type?

The stakes involved in pipeline transport, as an invisible facility, being installed in just about every possible underground alignment, remain unknown for the most part to the general public, especially given the extremely low accident frequency (zero accidents in the past 10 years on the transport network, only a few on the CPCU Company's heat distribution network and none since 2003). Various accidents affecting gas distribution pipes however have made their presence and risks more prominent. In the Paris Region alone, on average a distribution pipe has to be shut down due to leaking 4 times a day!

The truth is that these networks are ageing. The very first distribution networks were laid in the 1920's (Paris heating); after World War II, they developed substantially, during a period of strong growth and building of major infrastructure. These networks kept up with the increasing needs of residential comfort, as well as with the expansion in regional demographics, the switch away from coal and wood in favour of petroleum fuels and natural gas. The geological structure of the Paris Basin, which allows for the underground storage of gas resources, also facilitates laying gas transport networks in the area's outer periphery.

Determined policy efforts on the part of some municipalities and metropolitan areas to promote the construction of collective heat production and distribution facilities (incineration, cogeneration, geothermal) have added to the momentum behind heat network development.

The average age of these networks throughout France was 33 years in 2008 (44 years for hydrocarbon transport networks). Numbers like these have necessitated assigning new and more sophisticated monitoring and preventive maintenance resources, in order to avoid sudden accidental leaks.

The second area of heightened vigilance for public authorities clearly relates to controlling urban growth and restricting building activity adjacent to these pipelines. The density of Paris Region transport networks has prompted close scrutiny of the conditions guiding urbanisation within their vicinity.

As regards approved building projects, enactment of the new regulation that requires informing all elected officials via public disclosure statements is to be applauded for now making it possible to manage all new building works located near these pipelines and to anticipate the means for heightened protection.

This new regulation also proves quite important for feedback on existing conditions. Gas and fuel transporters are required to update their safety studies on all transport pipelines before September 15, 2009 and then implement programmes to raise the level of pipeline safety to make it commensurate with the actual risks incurred.

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Research in the area of good practices and use of the best techniques available are to be emphasised when seeking to attain a level of continuous improvement in risk control and management. It is well known that a detailed accident analysis, coupled with feedback control, helps identify target areas so as to avoid subsequent accidents. It is my hope therefore that the presentations and discussions shared over the next two days will be as enriching as possible and that these exchanges will provide positive input to the strategic assessments and responses required from you in carrying out your missions.

In closing, I'd like to express my warmest gratitude to all those who contributed to the organisation of this seminar. Thanks for your attention and once again welcome to our region.

Irreversible sinking of the floating roof on a crude oil tank

18 July 2007

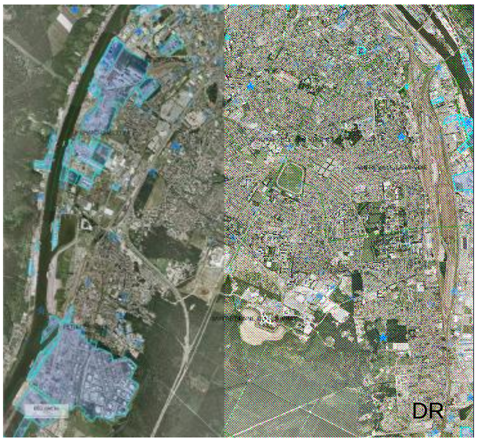
Petit-Couronne (Seine-Maritime) France

Atmospheric emissions
Petroleum refining
Fixed storage
Hydrocarbons (crude oil)
Floating roof
Volatile organic compounds
Rainwater network (stormwater drain)
Organization
Periodic inspections

THE FACILITIES INVOLVED

The site:

Located within a port zone in the immediate vicinity of the town centre and around ten kilometres from the regional capital city of Rouen, the Petit-Couronne refinery began operations in 1929. Its annual capacity of 7 million tonnes of crude oil places this installation in the medium size range as far as European refineries are concerned. The activities performed onsite fall under the jurisdiction of two European directives: Seveso (specific to the prevention of accidental risks), and IPPC (integrated pollution prevention and control, chronic risks).

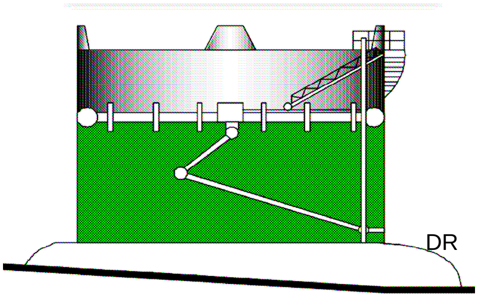


This facility has been divided into two zones, separated by a departmental highway. The first zone combines the refining units, while the second accommodates the raw material (crude oil) storage depots, intermediate distillate cuts and finished products (gases, liquid hydrocarbons as a fuel product, petroleum cuts intended for the petrochemical industry). This storage zone, named "Parc de Milthuit", is composed of both aboveground installations (tanks and storage spheres) and underground capacities (LPG storage caverns).

The involved unit:

The responsible facility is an aboveground crude oil storage tank with a total geometric capacity of 60,000 m^3. This cylindrically-shaped tank features the following dimensions:

- Diameter = 70 metres, yielding a cross-section of 3,850 m^2
- Shell height = 17 metres
- Tank contents stirred by means of 3 inclinable helical paddles
- Description of the tank roof: a 480-tonnes double-pontoon floating roof equipped with a 4" stormwater discharge drain and a 4" diameter weir (overflowing directly inside the tank) designed with the objective of avoiding immersion due to overloading. The double-pontoon roof is composed of several concentric circular caissons, with only the outer caisson actually being compartmented. The roof joint is of the "primary and secondary sheet metal compression" type with a dipping cover plate.



- Liquid level measurement using radar probes embedded in vertical tubes (guide tubes).
- Tank fitted with 12 foam boxes, offering a capacity of 800 litres per minute.

THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

The accident:

Tank B962 was filled without any special difficulty over the period from June 30 to July 2, 2007. Its contents were intended to provide a charge to the refinery's atmospheric distillation unit beginning on July 24. During the early morning of July 2, the tank was declared to be immobile without the centralised supervision of installations able to monitor the liquid level, so as to detect anomalies or eventual leaks in either the tank or its ancillary piping.

Several thunderstorms struck bringing heavy rainfall as of July 2. A 9.5-mm rain gauge reading was logged over a 24-hour period on July 3. Sixty-minute readings of 11 mm and then 23 mm were recorded during the night of July 3rd to 4th. Several level alarms on this tank (for a high operating level) were activated beginning on July 2nd. These alarms were not perceived as a potential anomaly by control room technicians, who elected not to initiate a level verification procedure specifically regarding the tank roof. Only visual inspections at the base of the tank were undertaken, since the floating roof caissons were successfully controlled on March 6, 2007 within the scope of a tank preventive maintenance campaign. Nonetheless on July 18, the refinery's materials accounting office announced the presence of an anomaly in crude oil flow levels. In response, the site operator on July 19 conducted a visual verification of the roof and detected roof subsidence without being able to determine whether it had irreversibly sunk or become misaligned with respect to its bracing.

As a preventive measure, the operator placed a high-powered fire protection vehicle adjacent to the suspect tank basin throughout the period of product pumping and crude oil transfer into a neighbouring tank. These steps actually took several weeks to complete (nearly 3 months in all). Despite the presence of functional foam boxes on the tank shell, the operator did not adopt any special measure to prevent crude oil from evaporating from the upper part of the tank contents, instead assuming that the application of a foaming solution might be the source of vapour ignition (out of fear of a static electricity phenomenon).

Consequences of this accident:

Despite requests voiced in unison by both the classified facilities inspection authorities and the Prefecture's civil protection agency, the operator, in recognition of a lack of regulatory threshold values for brief exposure periods of the general public to hydrocarbons (particularly benzene), did not notify the town's Mayor of the incident nor of appropriate precautionary measures that the local population should implement.

High hydrocarbon concentrations (reaching 25 mg/m^3 as an hourly average on July 8) were recorded between July 4 and August 31 on an air quality monitoring sensor set up in Petit-Couronne at a site 1.2 km from the suspect tank. An hourly average benzene value of 25 µg/m^3 was also recorded on this same sensor. Benzene values of 4.5 and 6.5 µg/m^3 of air over a 14-day period were logged respectively for the date ranges of June 30-July 12 and July 13-27 on a second sensor positioned approximately 2 km from the problem spot. Responsibility for installing and maintaining these sensors as well as interpreting their results was commissioned to an air quality control association, whose credentials included a certification awarded relative to the 1996 Air Quality Law. The annual average benzene level ultimately amounted to 2.1 µg/m^3 of air in 2007 vs. 1.6 in 2006 on the second sensor (the air quality threshold value on the benzene parameter had been set at 8 µg/m^3 as an annual average for all of 2007).

Several complaints were registered between July 22 and August 19 by the monitoring association, stemming from residents of towns located along the predominant downwind paths from the refinery.

The operator evaluated the quantities of volatile organic compounds accidentally emitted into the atmosphere to be 3,185 tonnes, of which 55 tonnes were accounted for by benzene.

The European scale of industrial accidents:

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

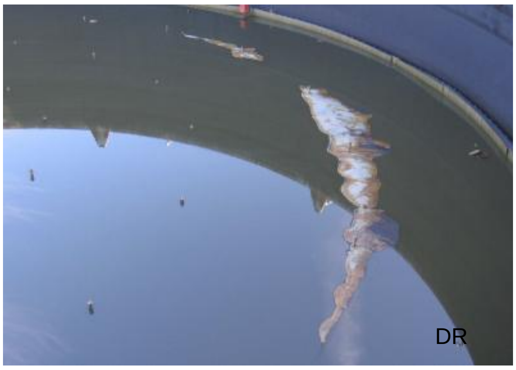
The quantity of benzene released into the atmosphere was assessed at 55 tonnes, i.e. 28% of the upper-tier Seveso threshold for a toxic gas, as set in the directive at 200 tonnes. Consequently, the "hazardous materials released" index climbed to a level 4 (parameter Q1).

The amount of the economic impacts was not made available. The operator was however able to evaluate the loss of operating margin at $5 million.

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

THE ORIGIN, CAUSES AND CIRCUMSTANCES SURROUNDING THE ACCIDENT

The inside of the B962 tank had not been inspected since 1993. Sediments had accumulated on the side opposite the paddle stirrers, without any of the visual inspections during periodic preventive verifications of the roof allowing for sediment detection. This height turned out to be above the height of the props (1.80 m) on which the roof rests when the tank is empty.



Repeated bending stresses on the caisson seal welds each time the roof lies on sediments had caused the localised break of several welds, as well as the filling of some caissons with crude oil.

This hypothesis ("V"-shaped convex folding of the roof) was confirmed in observations recorded by the operator on the roof state, its shell, waveguide tubes and plates used to obstruct tube crossing.

When the roof was in the upper position, the precipitation events occurring at the beginning of July led to a sizable quantity of water accumulating both above the floating roof (at a height corresponding to 4 overflows) and in the tank. Perforated and isolated from the network of potentially oily water by means of a manual shutoff valve at the tank base placed in a closed position, the stormwater discharge drain could not function properly and contributed to sinking the roof.

The quantities of crude oil trapped inside the caissons and water accumulated on the roof caused the tank to lose its flotation capacity subsequent to the unequal charge distribution and eventually to its irreversible sinking.

ACTIONS TAKEN

The classified facilities inspection authorities were informed of the incident by the operator on July 19, 2008 at 6:27 pm. On July 20, inspectors showed up onsite unannounced in order to collect accurate information on accident chronology and gain familiarity with the intervention strategy implemented in case of fire.

A management meeting was held on July 25, 2007 at the request of the Prefecture's civil protection agency to discuss how to coordinate the allocation of emergency resources (also in attendance at this meeting were representatives from the departmental fire services unit).

Experts from the petroleum group responsible for refinery operations in 2007 underscored the fact that the foaming solution (water/emulsifier mix) application rates recommended differed by a factor of 3 from those stipulated for fire outbreak in the safety reports. Moreover, the site was not equipped with an adequate water supply (insufficient fire mains flow rate) to allow implementing the expert group recommendations as regards water usage rate.

The operator transferred via a gravity system the tank contents into other refinery tanks until a time when the liquid level neared that of the roof, which had stabilised at 2.8 m.

A high-pressure cut-out of the roof shell and then water injection in the tank were carried out to allow pumping out the remaining hydrocarbons. These efforts would continue until mid-November and entailed extracting the full liquid contents in the tank plus the deposited sediments.

Follow-up inspections were conducted during both 2008 and 2009 to ensure that operator practices with respect to tank interior verifications and the reliability system in place for overseeing and managing immobile tanks had indeed been improved.

LESSONS LEARNT

1 - Monitoring of the sediment level at the tank bottom (evaluations or appropriately-spaced inspections) constitutes an essential element to ensuring roof horizontality when in the lower position and, afterwards, its continued structural integrity.

2 - Closure of the stormwater valve located downstream of the drain is capable of causing an excess load on the roof. The hydrocarbon content of stormwater in the drain provides an indicator of deterioration in the drain seal, or even in roof caissons.

3 - Even though no fire broke out in Petit-Couronne despite meteorological conditions that could have increased the chances (high temperatures coupled with the risk of summer lightning), accident statistics reveal that operating conditions (malfunction of the flare at MILFORD HAVEN in 1983, vehicle traffic adjacent to the tank at SKIKDA in 2005), natural triggering events (lightning at BERRE in 1994) or inappropriate intervention measures (foam projection by a hose gun generating triboelectric phenomena, followed by electrostatic discharges, in the central part of the roof at ESSEX in 1991) can all lead to igniting hydrocarbon vapours as a result of a defect in the floating roof.

On the other hand, spillways laid out on the tank shell made it feasible in KARLSRUHE during June and July 1999 to smoothly introduce a foam carpet without igniting the vapours. This operation entailed spreading foam from the tank walls instead of projecting it by hoses from the ground.

4 - According to the overall risk management approach addressed in the safety report, prevention plan or emergency action plan, the phenomena corresponding to hazardous substance emissions into the atmosphere must not be overshadowed by the potential for fire or explosion, in noting that the effects, conditions, precautions, means of intervention and consequences are all fundamentally different in nature. As such, the cases of floating roof locking or sinking are not so infrequent as to be ignored.

5 - The safety reports must pay special attention to the following:

- the possible health consequences for the general public, especially as regards the reference toxicological values available for toxic substance exposure via a sufficient inhalation period,

- an evaluation of "explosive atmosphere" zones and measures adopted to prevent their ignition,

- potential mitigation and intervention steps in the event of roof immersion,

- foreseeable emergency measures (confinement, discharge, etc.).

Degassing of a tanker truck containing waste

31 July 2007

Limay (Yvelines)

France

Waste
Degassing
Tanker truck
Exothermic reaction
Decomposition
Procedures / guidelines
Internal Emergency Plan
Oxygenated water

THE FACILITIES INVOLVED

The site:

The Limay processing centre for hazardous industrial waste, which features an annual capacity of 250,000 tonnes, utilises various treatment procedures depending on the type of waste received:

- combustion furnaces for liquid, paste or solid waste,
- an evapo-incineration furnace,
- physicochemical treatment unit,
- residue stabilisation unit,
- waste unpacking and pre-treatment units.

The involved unit: Incineration unit

Waste materials are received either in bulk or pre-packed and then moved to storage in designated zones: aboveground vats for liquids, ditches for solids and pastes.

For certain types of waste, it may be decided to treat them by direct injection as an incineration process from the tanker truck parked adjacent to the unit.

Waste is conveyed to the combustion furnace intake and then to a rotary furnace. A pre-treatment step (drying) is applied to the sludge according to its level of dryness, prior to introduction into the furnace.

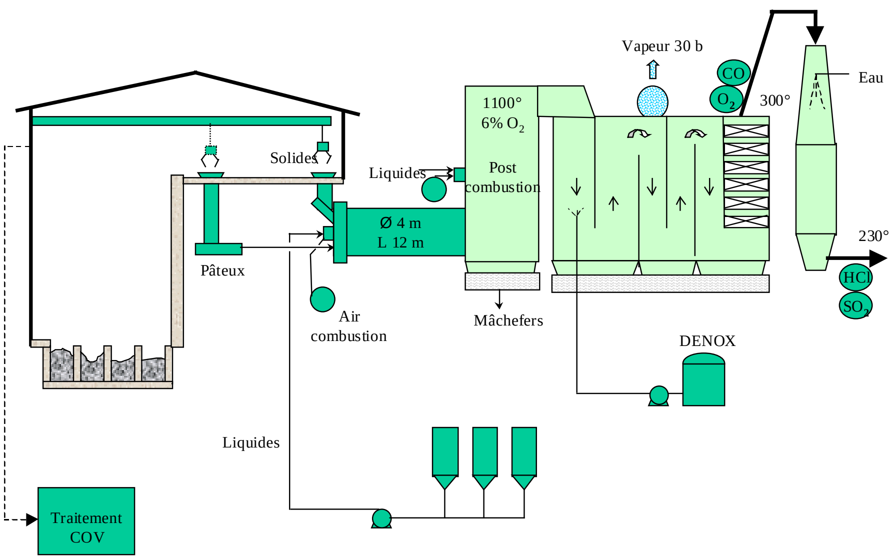


Diagram of the incineration process

The incineration process takes place over several stages: combustion, cooling of gasses, and gas treatment.

Fume purification residues are then conveyed to the site's stabilisation-solidification unit.

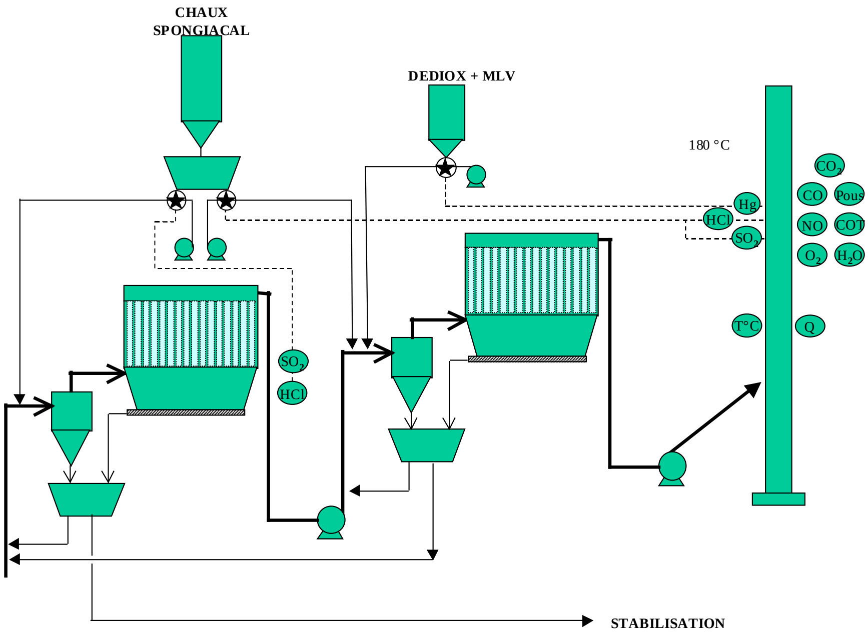


Diagram of the fume treatment process

Waste acceptance protocol:

The onsite acceptance protocol for hazardous wastes is as follows:

- The first step consists of identifying and characterising the specific type of waste before its arrival onsite, by means of a representative sample furnished by the waste producer, and offering judgment on waste suitability depending on both its characteristics and the site's capacity to provide treatment. A preliminary acceptance certificate is then sent to the client and an appointment set to receive the waste.
- Upon its arrival onsite, the shipment of waste must be accompanied by a waste tracking slip. Compliance of this slip along with the acceptance certificate is verified and a sample extracted for analysis in order to ensure a match between the waste received and the certificate and tracking slip details, ultimately with the aim of conducting specific analyses to refine treatment. The package of waste is then transferred to the appropriate installation.

Feeding the furnace with liquid waste:

The liquid waste is conveyed to the point of furnace injection by means of a set of pumps and racked pipes. The distribution array, laid out adjacent to injection points, feeds the injection tubes where the liquid is pulverised by compressed air. For each line of waste, the array recomposes the flow measurement and safety sectioning instruments. Each flow rate is automatically adjusted on the basis of furnace operating parameters.

THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

The accident:

Waste acceptance:

The waste at the origin of this accident was a mix of 30% hydrogen peroxide and 5% acid resins; it was the by-product of an unloading error that occurred on May 29, 2007 within a paper mill complex in Jouy-sur-Morin (Paris Region, Seine-et-Marne Department). This error caused an exothermic reaction of the mix and necessitated the onsite presence of local fire and emergency personnel along with evacuation of the entire plant.

The waste processing centre was called on May 29 to undertake the immediate removal of 40 tonnes of waste involved in this incident; due to a lack of detailed information, the centre initially refused the request. After analysing a waste sample and stabilising the waste at room temperature, the centre agreed to an incineration-based treatment by direct injection into the furnace. A preliminary acceptance certificate was issued on June 1, 2007.

In an e-mail message sent on June 7, the paper mill requested the processing centre to suspend the outlined waste removal procedure as of June 11, since the mill was studying the feasibility of an in-house neutralisation solution as a means of limiting reprocessing costs. Following investigation, it was clear that neutralisation tests conducted on several samples of these wastes, at the production site, were not conclusive.

The mix contained in two of the vats was pumped on July 30, 2007 into a stainless steel, single-compartment tanker truck. The first vat could be completely emptied and the second to a partial extent.

The waste was delivered to the processing centre on July 30. A sample was extracted and, following acceptance, the tanker truck was routed to the site's direct injection zone for unloading into furnace no. 1.

Chronology of events:

On July 30, 2007 at 3:52 pm, the tanker truck arrived at the site.

At 5:45 pm, the direct injection line was rinsed with water before being connected to the tanker truck.

At 6:15 pm, incineration operations began.

At 9:00 pm, the direct injection line was obstructed. It was unplugged and nitrogen was injected via a vent on the truck, in an effort to "push" the waste through. The truck's valve was left open.

On July 31 at 3:00 am, leaks on the truck's second manhole were still ongoing. The incineration operation was halted. The underflow gate was closed and the nitrogen injection circuit isolated, yet the hose connecting the tanker truck to the direct injection pump was still hooked up to the truck.

At 4:00 am, the hose connecting the truck to the injection pump burst. The truck at this point was "very hot".

At 5:30 am, the truck was still "hot".

At 8:30 am, the temperature of the tanker truck sidewall was estimated at between 30° and 60℃. The ve nts were open and the truck was sprinkled by the spraying ramps located in the zone dedicated to direct processing operations.

By 12:00 noon, both the truck temperature and pressure were rising. The truck was moved outside the direct processing zone to install a "peacock fan"-shaped spraying device on each side of the truck. The valve on the site's industrial effluent and stormwater containment pond was then closed.

Around 1:30 pm, teams on the site's second shift arrived as a backup to continue spraying the tanker truck with fire hoses. In order to lower pressure, the truck was emptied of a few containers loaded with the mix, and these containers were placed adjacent to the truck. A safety perimeter was established.

The onsite teams chose to set up a water cannon in order to protect personnel from exposure. It was then decided to move the personnel to safety and call the emergency services unit.

At the same time, 2:30 pm, the internal tanker truck pressure rose and the manhole located on the back face of the truck broke open. The truck degassed all at once; then, both the truck and tractor were propelled some fifteen metres due to the effect of this pressure burst and came to rest when reaching the edge of the track.

Photographs of the tanker truck and the various spraying set-ups (reconstitution – Source: site operator)

Consequences of the accident:

Just after the accident, a local evacuation notice for the zone was broadcast. Staff members at the nearby laboratory were evacuated to another zone on the same site, whereas office employees were told to remain indoors and not allowed to leave. Vehicle entrance bays were shut. A safety perimeter was marked off around the tanker truck. Truck cooling was facilitated using a fire hose. A message announcing the end of this alert was broadcast around 3:00 pm on the 31st.

Three employees were slightly hurt: facial irritations, and a partial foot burn; they were all taken to hospital.

Nine other people showed up at the site infirmary with benign injuries.

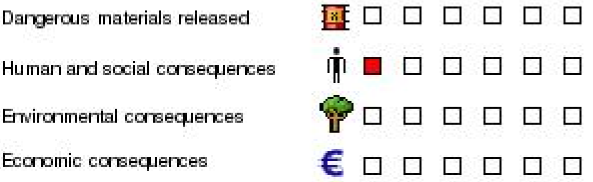
No major property damage was declared (deformation of some metal cladding), except for the tanker truck itself, whose braces and hood were bent.

The quantity of mix released into the atmosphere, in the form of droplets and O_2 remaining from peroxide decomposition, was estimated at less than a tonne (approx. 600 litres).


Burst manhole cover (Photos courtesy of the site operator)

The European scale of industrial accidents:

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



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

The rating of the "hazardous materials released" index equalled zero since the 30% hydrogen peroxide is only considered to be a combustive substance as of a 50% concentration.

Level 1 of the "human and social consequences" index was reached due to the fact that three people were injured.

Environmental consequences were limited and very point-specific: degassing of the tanker truck. The water used to cool the truck, subsequently mixed with the waste contained therein, was confined (approx. 150 m^3) by the retention basin.

The lack of accurate information on economic consequences of the accident makes it impossible to determine the index rating corresponding to the European scale.

THE ORIGIN, CAUSES AND CIRCUMSTANCES SURROUNDING THE ACCIDENT

Waste pumping at the production site:

The paper mill indicated that it had not modified the waste during neutralisation testing conducted solely on samples and moreover had not noticed any heating during waste loading into the tanker truck. The pumping stage using new hoses was carried out onsite.

Inspection of tanker truck contents upon arrival:

The sample taken from the truck, for the purpose of declaring acceptance or not at the processing site, was similar in composition to the one received for preliminary acceptance determination, yet showed slight instability (a few bubbles that were not mentioned on the material transfer form). Truck temperature was not verified by the sampling technician. The material transfer form listed the results of analyses performed and confirmed routing to the direct incineration unit. The tractor then towed the tanker truck to the required spot (direct treatment zone) and left it there.

Preparation for the incineration step:

Racking of this tanker truck could not begin immediately since the injection line was already in use for another vat. The incineration unit had been forewarned of the need to use a clean set of bleeding lines and buckets. The direct injection lines were rinsed with water prior to initiating tanker truck pumping.

Origin of degassing:

The decomposition of hydrogen peroxide led to a sudden degassing of the tanker truck. The H_2O_2 decomposition reaction is an exponential speed reaction. Defining with certainty the exact time when the product starts to react proves to be a difficult step, since inertia runs high in a tanker truck carrying 25 tonnes. This reaction was in fact able to begin prior to waste acceptance: before/during loading, at the same time as the transport?

A number of questions still remain:

- The waste was able to undergo modifications during treatment tests conducted by the producer, between the date of sample transmission and the date of waste acceptance;
- The mixing of both vats at the time of pumping also served to trigger the reaction. This information relative to the two-vat mix was only received after the accident at the processing centre.

An additional sample was extracted from the truck on the morning of July 31st, as the temperature inside the truck was starting to climb. This sample revealed a lower H_2O_2 rate than that recorded the day before, which confirms a progression in the reaction, yet the analysis was undertaken following the accident. The incineration unit had been advised to use clean bleeding lines and buckets but had not been formally notified by the laboratory of an eventual risk of pressure rise.

The unloading method employed did not enable coping with the risk of waste degassing:

- The selected unloading line was operated by either suction or nitrogen thrust; it lacks a specific relief valve system that could have allowed releasing the gas formed during the reaction;
- Only the tanker truck valves could have ensured proper aeration and the requisite evacuation of gas bubbles; these valves however proved inadequate for this particular waste within this particular volume.

Internal Emergency Plan

The Internal Emergency Plan had not been activated since the various scenarios did not feature either hydrogen peroxide degradation or a tanker truck rupture as the consequence of an uncontrolled chemical reaction; the situation did not present any fire or explosion risk and the toxic risk was controlled by water curtains. Nonetheless, the set of actions actually initiated in response to the event did correspond to the measures indicated in this emergency plan.

ACTIONS TAKEN

Immediate measures adopted:

In order to avoid and limit the consequences of a similar accident, the operator decided to:

- introduce the systematic verification of tanker truck temperature at the time of material acceptance (with all pertinent information recorded on the material transfer form);
- refuse the acceptance of wastes containing hydrogen peroxide in bulk packaging exclusively for concentrations below 5%, and require wastes containing higher concentrations to be shipped in barrels or containers.

Prescriptions issued, request for remedial actions:

By way of Prefectural order adopted on August 22, 2007, the Yvelines Department Prefect's Office suspended the acceptance of composite wastes, either partially or fully, containing highly-concentrated combustive products, especially a mix of hydrogen peroxide and acid resins remaining on the paper mill site. This edict was issued while awaiting submission to the classified facilities inspection authorities of the summary report on an analysis of causes and deficiencies leading to the July 31, 2007 accident.

Inspection authorities stated that the set of measures specific to the internal emergency plan established by the Prefectural order approving the site were not respected.

Non-activation of the emergency plan meant that the fire and rescue unit was not informed and moreover that the unit's technical resources were not mobilised to prevent the exacerbation of an accidental situation. More specifically, air quality measurements in the vicinity of the tanker truck, in the case where the truck had been degassing for several hours, were not completed.

Subsequent to this accident, a number of site safety management system improvements were anticipated: re-evaluation of waste acceptability controls (including the physical magnitudes that enable tracking a potential evolution in loading behaviour), assessment of risks relative to tanker truck parking near industrial installations and high-risk zones, and re-examination of the decision-making process that leads to activation of the internal emergency plan.

Corrective actions undertaken by the operator:

⇨ Introduction of a guideline relative to the oversight of high-risk material deliveries that addresses the following points:

- acceptance of waste subject to agreement by the site's Safety Coordinator,
- preventive measures to be developed, disseminated and verified by the site's Safety Coordinator,
- a set of situation degradation indicators need to be defined,
- potential scenario(s) specific to the internal emergency plan are to be anticipated;

⇨ Stricter acceptance procedures for wastes containing hydrogen peroxide: accepted in bulk solely with concentrations of less than 5%. For higher concentrations, wastes are only accepted in barrels or containers;

⇨ Reinforcement of waste acceptance controls: a temperature control must be performed during sampling from the tanker truck. The result of this control step is to be formalised on the material transfer form;

⇨ Modification of the internal procedure governing "emergency situations and reaction capacity", for the purpose of formalising how degraded (yet non-emergency) situations are handled. For all such modifications, a meeting must be quickly organised with the facility Director, Head of Operations, Unit Managers concerned and the site's Safety Coordinator, with the aim of determining: the measures to adopt, the degradation indicators to monitor, potential emergency plan scenario(s), and the measures and indicators tracked by the Safety Coordinator;

⇨ Enhanced formalisation of the emergency plan activation process;

⇨ Oversight of emergency plan training and exercises in order to familiarise all involved parties with emergency plan scenario management;

⇨ Reminder circulated to ensure that the zone assigned onsite for "suspicious" loads gets used whenever necessary. This zone resembles an isolated storage and is located in the north-western sector of the site; it is equipped with two fire hydrants and a fire protection system installed just opposite this storage zone.

⇨ Coordination of efforts with the emergency response units: modification of emergency plans, and addition of a new scenario involving the intervention of external rescue personnel. This scenario corresponds to deterioration in a treatment situation for a high-risk, yet controlled, waste. The inclusion of this scenario enables emergency units to record the event and implement suitable resources gradually without necessitating a critical accident situation.

LESSONS LEARNT

The primary cause of the sudden tanker truck degassing was the decomposition reaction initiated within the waste contained in the truck. The accident analysis has shown however that not only were the waste material acceptability controls insufficient, but the safety measures in place at the time were inappropriate.

The treatment of hazardous waste requires a safety management system that includes the following:

- characterisation of the targeted materials (pH, temperature, colour, viscosity, odour, etc.), controls and testing for chemical compatibility between substances, verification of the absence of phases within the mix, and any immediate undesirable chemical reaction or deviation in material characteristics over time;

- assignment of responsibilities to be more clearly specified and adapted to all operations planned by personnel or contractors involved at the processing site;

- technician training in hazard prevention, specifically for the steps of material unloading and transfer (with the possible presence of residual toxic or inflammable gas, etc.);

- indications of measures to be adopted in the event of an incident or deviation in operating procedure;

- introduction of measurement, detection and monitoring devices;

- documentation for the entire series of procedures, from acceptance of hazardous waste through its elimination, with recording of critical parameters and characteristics as regards safety.

Blaze at an ethylene pipeline and a nearby acrylonitrile tank

17 March 2008

Köln (North-Rhine-Westphalia) Germany

Ethylène
Acrylonitrile
Pipeline
Tank
Insulating flange
Gate valve
Fire
Maintenance work
Organization / procedure

THE FACILITIES INVOLVED

The site:

The accident happened in the northern part of Cologne on the site of a petrochemical plant of the company. The plot of the company is situated in an industrial area for mainly chemical companies. The company is the third largest chemical enterprise in the world. It's a leading manufacturer of petrochemical, special chemical and oil products with 70 production sites in 14 countries. The site, with its 2200 employees, a production volume of 5 million tons and a turnover of 2.6 billion euros, is the biggest chemical site in Cologne and one of the most import locations of the group. The plant is connected to an international ethylene pipeline net - owned by another company - that is used by the plant for consumption as well as injection of ethylene. At the day of the accident ethylene was injected into the net. The shortest distance from the location of the accident to the next inhabited area is about 600 meters.

The involved unit:

The accident happened at the blocking station of the international ethylene pipeline owned by a company which is a joint venture of six international chemical companies including the company of the plant. The blocking station is situated at the transition from subsurface to surface course of the pipeline. It is equipped with a remote controlled hydraulic gate valve, an insulating flange and a bypass with manual gate valves (Figure 1). The diameter of the pipeline is 250 mm and of the bypass 80 mm. Ethylene is produced by the company form LDF - light distillate feedstock (light petroleum) - and used for the production of polyethylene. At the time of the accident about 27t/h of ethylene were injected into the pipeline under a pressure of 83 bars. The pipeline is assigned to the German pipeline regulation, the so called "Gashochdrucksleitungsverordnung". Pipelines are excluded from the Seveso directive.

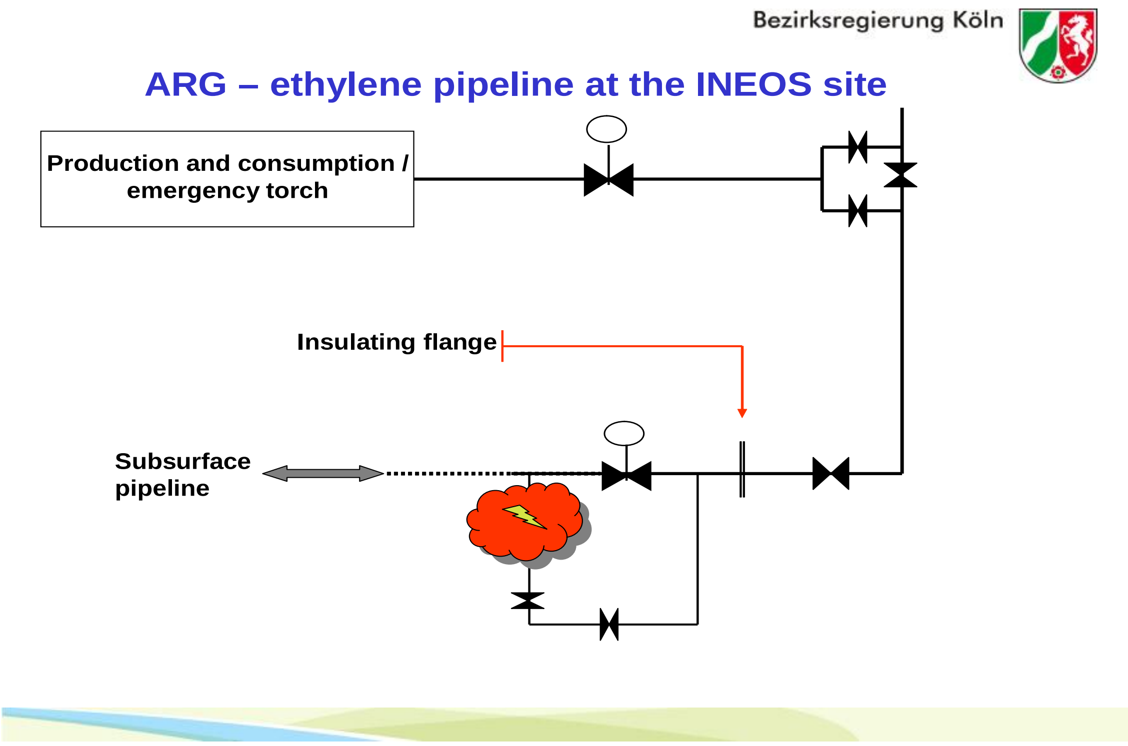


Figure 1: Scheme of the ARG ethylene pipeline at the site.

A tank field for the storage of acrylonitrile - an upper tier Seveso installation - is situated in the direct vicinity of the blocking station (Figure 2). The nearest of the three tanks with a distance of about 10 meters to the pipeline was filled with 3517 cubic metres of acrylonitrile. The height of the tank with attached ceiling is 16 metres and its diameter is 18 metres. The wall and the ceiling of this tank are made of aluminium. It is surrounded by a concrete wall of identical height with a distance of 1.2 meters from the aluminium wall. This concrete wall also serves as retention basin. At the time of the accident about $14 m^3/h$ were taken from this tank. The site mainly uses acrylonitrile for sale to the plastics producing industry.

THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

The accident:

At 2:26 pm a leakage at the insulating flange of the ethylene pipeline blocking station was induced and/or detected during the execution of maintenance work. At 2:28 pm the leakage was announced to the operator of the ethylene pipeline by the plant. Two minutes later the remote controlled hydraulic gate valve was locked.

From the moment of the announcement on there is a video recording of a surveillance camera that was directed to the transfer station and the near by tank field. On this recording the exhausting gas is detectable. 7 minutes after the beginning of the leakage the ethylene ignited as can be seen on the video recording (Figure 2). At 2:32 pm the plant fire brigade arrived at the scene and - after the ignition of the ethylene – began with cooling of the nearby acrylonitrile tanks.

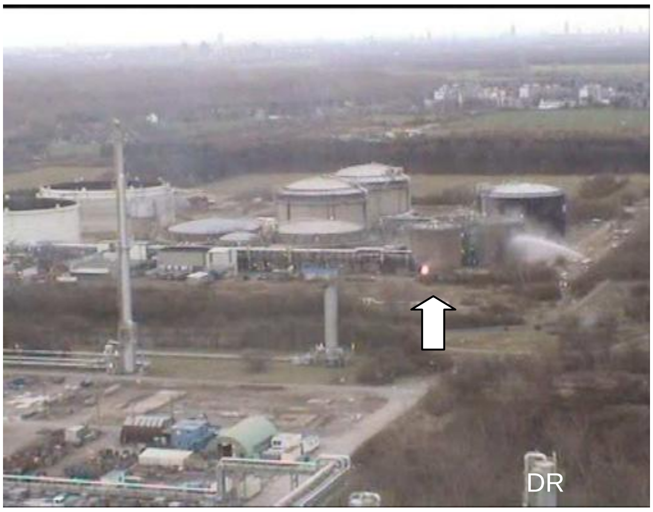


Figure 2: Ethylene flame from the leakage at the insulating flange (arrow) and cooling of the acrylonitrile tanks by the fire brigade

Immediately after the announcement, the injection of ethylene from the plant was stopped, the injection valve was blocked and the remaining gas in the transect was directed to an excess gas burner(Figure 1). In consequence of the leakage and these measures the gas pressure dropped from 83 bars to a few mbars within 12 minutes. Simultaneously the gas temperature dropped from 16℃ to -30℃. Sho rtly after the ignition the height of the flame was about 3 to 4 meters with decreasing tendency. At 2:36 it had nearly gone out in consequence of the decreasing gas pressure. But from 2:38 pm on it increased again and after a short time it set the hydraulic valve under fire which was only two meters away from the insulating flange. A reason for this was probably the destruction of the hydraulic oil tank at the valve in consequence of the high flame temperature. Short time before the fire brigade had begun with cooling the acrylonitrile tanks to guard them against ignition. Maybe some of the cooling water drifted to the burning pipeline because of the small distance to the neighbouring tank. A few seconds later the hydraulic valve and the bypass were completely under fire (Figure 3).

Figure 3: Increasing of the flame in direction of the hydraulic valve and the bypass. Support of the flame by the hot and inflammable hydraulic oil from the broken holding tank of the valve is most likely.

As a consequence the ethylene in the bypass and pipeline on the other side of the gate valve, which was still under pressure of 83 bars, was dramatically heated by the flames. This eventually caused the decomposition of the ethylene in the pipeline with an enormous increase in temperature and pressure. Due to these events the bypass was destroyed and the pipeline opened up again. Now all of the ethylene in the pipeline under a pressure of 83 bars was released into the burning surrounding. The next gate valve was situated at a distance of about 11 km. It was closed two minutes before the bypass gave way. But there were still 200 tons of ethylene in this transect of the pipeline.

Immediately after the destruction of the bypass at 2:43 pm a jet flame with a height of about 30 to 40 meters formed in the direct vicinity of the acrylonitrile tank (Figure 4). This flame burnt with the same height until 5:30 pm, then began to decrease until it extinguished at 7:26 pm. From 3:00 pm on the Cologne fire brigade a lot of other auxiliary fire brigades supported the fight against the fire.

Figure 4: Ethylene jet flame from the broken bypass of the gate valve; gas pressure: 83 bars. Half an hour later the nearest acrylonitrile tank caught fire.

The neighbouring acrylonitrile aluminium tank was surrounded by a protecting concrete wall but without concrete on top of the tank. Because of the enormous heat radiation of the jet flame (about 2000 °C) plastic components of the fire engine at a distance of 50 meters began to melt as well as parts of the aluminium tank ceiling. First flames formed at the top of tank at 3:12 pm. From 4:30 pm on the whole roof area of the tank was burning (Figure 5). The flames reached a height of about 16 to 20 meters. At this time about 35,000 litres per minute of quenching water were used for extinction of the fire as well as for cooling of the surrounding tanks.

The inhabitants of the nearby districts of Cologne were warned and requested to close the doors and windows. But at this time the cloud of smoke rose straight to an altitude of about 700 meters in consequence of the thermal lift. Due to a considerable deployment of measuring units the dissemination of the polluted cloud was well tracked. For that purpose the fire brigade also was supported by the well equipped measuring unit of the State Environment Protection Agency. At some measuring points positive results were found for nitric oxides and hydrogen cyanide, but with 2–5 ppm for NOx and 2 ppm for HCN they were in the range of the detection limits.

Figure 5: Whole roof area of the acrylonitrile tank is burning at 4:30 pm.

Not only the ceiling but also the aluminium tank wall burnt down to the acrylonitrile liquid level which was about six metres below the ceiling. From this time on a mixture of water and acrylonitrile poured into the gap between the tank wall and the surrounding concrete wall. Due to the extreme circumstance cracks formed in the concrete wall. Now the stability of the whole tank was in question. A break down of the burning tank would have had grave consequences to the surrounding tank field, the fire fighters and the environment. So the fire brigade started an enormous foam attack on the tank and eventually succeeded in extinguishing the flames at 11:50 pm. Since the Second World War there was no fire in Cologne that demanded the deployment of 1180 fire fighters within five hours.

After extinction of the flames the temperature of the acrylonitrile was 75 °C, two centigrade below the boiling point. In succession of the strong wind and the associated holes in the foam layer some of the acrylonitrile evaporated batch-wise. As a consequence, acrylonitrile was found in the ambient air in the near by Cologne district Worringen in concentrations of up to 20 ppm.

Consequences of the accident:

There were no serious injuries as a consequence of the accident. Altogether 600 persons from the fire brigades, police and aid organisations participated in an investigation of acrylonitrile in blood samples. No result indicated abnormalities due to the operation. For the estimation of the seriousness of the found pollutant concentrations in the inhabited districts Emergency Response Planning Guidelines (ERPG) and Acute Exposure Guideline Levels (AEGL) were used (Table 1). Found concentrations of nitric oxides (2-5 ppm) and hydrogen cyanide (2 ppm) were well below the ERPG-2 limits of 15 respectively 10 ppm, which are one hour mean values!

Table 1: ERPG and AEGL

1. Emergency Response Planning Guidelines (ERPG)

ERPG-1: The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing other than mild, transient adverse health effects or perceiving a clearly defined objectionable odour.

ERPG-2: The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action.

ERPG-3: The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing or developing life-threatening health effects.

Acrylonitrile:

ERPG-1: 10 ppm (22 mg/m^3)

ERPG-2: 35 ppm (76 mg/m^3)

ERPG-3: 75 ppm (63 mg/m^3)

Source: AIHA - Emergency Response Planning Committee

2. Acute Exposure Guideline Levels (AEGL)

AEGL-1: is the airborne concentration (expressed as ppm (parts per million) or mg/m3 (milligrams per cubic meter)) of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic no sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.

AEGL-2: is the airborne concentration (expressed as ppm or mg/m3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long–lasting adverse health effects or an impaired ability to escape.

AEGL-3: is the airborne concentration (expressed as ppm or mg/m3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening effects or death.

AEGL values are developed for 10 minutes, 30 minutes, 1 hour, 4 hours and 8 hours

Acrylonitrile (ppm), status: proposed

	10 minutes	30 minutes	60 minutes	4 hours	8 hours
AEGL-1	4,6	4.6	4.6	4.6	4.6
AEGL-2	290	110	57	16	8.6
AEGL-3	480	180	100	35	19

Source: http://www.epa.gov/oppt/aegl/

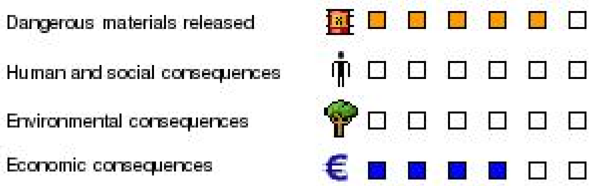
For the estimation of the acrylonitrile exposure in the Cologne district of Worringen a distinction was made between a main exposure area nearest to the incident with highest individual acrylonitrile values and the rest of the district (Figure 7). From March, 18th, until March, 23rd, altogether 506 single measurements were taken, 175 thereof in the main exposure area. The highest one hour mean value in this area was 10 ppm which is identical with the ERPG-1 value (Table 1). This value covers the time of 4:00 am until 5:00 am (March, 18th) while most of the inhabitants were in their houses. The highest eight hours mean value was 5.1 ppm which is 10% above the proposed AEGL-1 value (Table 1).

For the estimation of the acrylonitrile cancer risk a short study was established by the State Environmental Protection Agency of North-Rhine Westphalia. For this assessment the mean concentration over the whole exposure time is important. In the study a mean value of 1.7 ppm over a time period of 5 days was found in the main exposure area, outside this area the value was 0.3 ppm. From the 1.7 ppm value an additional cancer risk of 1:50,000 was calculated. An individual risk can not be deduced from this calculation. One also has to bear in mind that the found mean concentration over this time period is only valuable outdoors and that most inhabitants were in their houses during occurrence of the highest concentrations.

Immediately after the exposure 15 soil samples and 10 grass samples were taken from sensitive areas - like children's playing grounds, schools, kindergartens and so on - and were analyzed for acrylonitrile. In addition 5 soil samples and 5 plant samples from nearby acres were also investigated. All results lay below the detection limits in the range of <5 to <20µg/kg.

The European scale of industrial accidents

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



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

The amount of ethylene burned is 300 t. The ethylene SEVESO threshold being equal to 50 t, the amount released corresponds to 600 % of the threshold. The amount of acrylonitrile burned is 1 200 t. The SEVESO threshold being equal to 200 t, the amount released corresponds also to 600 % of the threshold. The indice related to the amounts of dangerous materials released for these percents is 5 (see parameter Q1). The property damage resulting fromf the accident in the establishment amounted to 19 M€, the establishment's production losses to 32 M€ while the costs of cleaning and decontamination are estimated to 2 M€. The indice related to the economic consequences is therefore equal to 4 (see parameters €15, €16 and €18).

THE ORIGIN, CAUSES AND CIRCUMSTANCES SURROUNDING THE ACCIDENT

For clarification of the facts leading to the accident two expert survey reports were commissioned. The first one dealt with the origin, causes and circumstances of the blaze of the ethylene pipeline and the acrylonitrile tank. The second one which was independent of the first one focused on the pipeline. The surveys confirmed that the pipeline and the tank were constructed and operated in accordance with the technical rules and the permissions before the commencement of the incident. Also the requirements of fire and explosion prevention were fulfilled and the necessary distance between pipeline and tank was kept. The accident could not have been predicted or restricted by any systematic risk assessment. The provisions in the alarm and hazard defence plan of the tank field were sufficiently accurate to initiate the necessary measures.

The influence of the maintenance work could not be clarified by the surveys because of an ongoing investigation of the department of public prosecution. But the expert figured out that a leakage at the insulating flange could evolve during the maintenance work when the sequence of the tightening of the screws is not followed correctly or when the wrong torque is applied.

Concerning the cause of the ignition of the exhausting gas both surveys came to identical results. The most probable mechanism of ignition was electrostatic charging because all other ignition sources could be excluded. According to both surveys the cause of the expansion of the fire and the following exposure of the gate valve and the bypass to the fire could not be clarified definitely. The most probable cause is the destruction of the hydraulic oil tank with subsequent leakage of the hot and inflammable hydraulic oil. The influence of the cooling water that came into contact with the hot hydraulic oil is discussed controversially. An insertion of drifting water droplets could not be avoided during cooling of the nearby acrylonitrile tank (Figure 4). As it is technical accepted to let a gas flame burn until the gas is consumed the fire brigade did not use the water for quenching of the gas flame.

The cause for the bypass breakdown was with high probability a thermal decomposition of the ethylene. Under certain pressure and temperature conditions the property of ethylene is to decompose explosively. Temperatures of up to 1500°C could occur during this process. According t o the surveyors the conditions for decomposition were given. Due to the spontaneous rise in pressure and the softening of the bypass caused by the flame heat the breakdown of the bypass was inevitable. The chain reaction - first burning of the exhausting ethylene and then destruction of the hydraulic oil tank with subsequent under firing of the bypass and eventually destruction of the bypass - could have been avoid, if there was a bigger distance between the insulating flange and the other fittings.

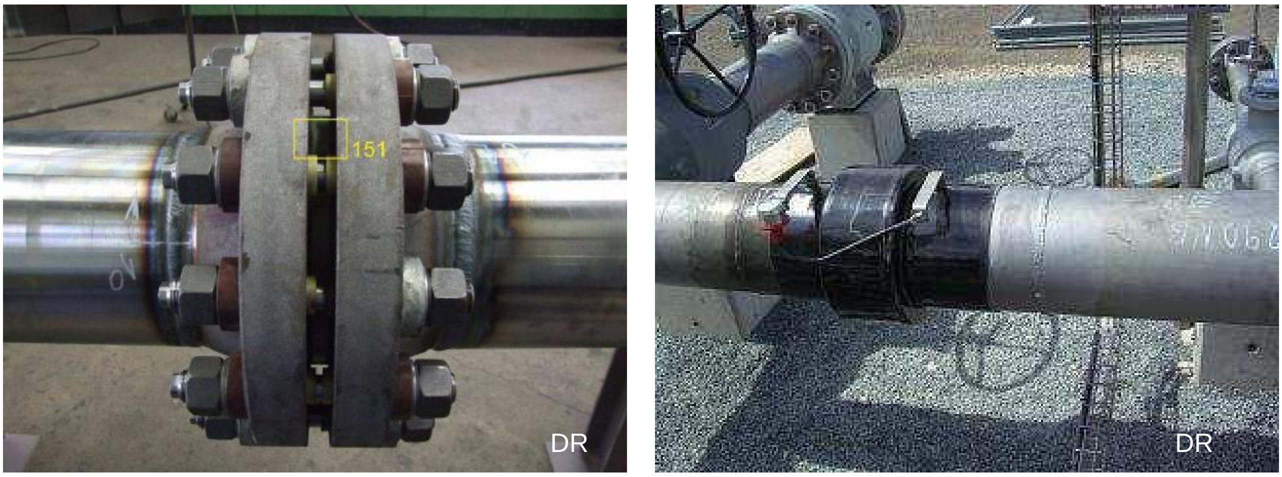
During the first phase of the fire the acrylonitrile tank was only marginally affected by the heat. Only from 2:43 pm on as the bypass was destroyed and the jet flame with a height of 30 to 50 meters appeared the tank was affected by relevant heat radiation. The survey comes to the conclusion that due to the long time of heat radiation and the direct flame exposure of the tank roof part of the aluminium roof melted and gave way to acrylonitrile vapour that ignited. The additional heat formation of these secondary fires had a supportive effect on the meltdown of the aluminium roof. At 4:30 pm the roof had completely melted down so that the complete tank square was free to burn.

ACTIONS TAKEN

The low contaminated water used for cooling of the acrylonitrile tanks was given to Currenta´s own waste water treatment plant and after purification discharged into the river Rhine without exceeding of emission limit values. The mixture of fire water and acrylonitrile from the tank was given to an incineration facility. The tank remains were removed to give place for a new construction. The ethylene pipeline was displaced and the blocking station reconstructed at a distance of 62 meters from the tank field. The insulating flange with inserted nuts was removed by a maintenance-free welded insulating connector (Figure 8).

The Cologne District Government as competent authority developed a concept of measures related to Seveso sites that are operated in close vicinity to pipelines with inflammable gases. As a first step the operators of such sites were requested to register the pipelines in the vicinity of Seveso sites. Priorities for registration were pipelines with highly inflammable and inflammable gases. In this survey the operators were also asked to describe the technical construction of the pipelines with emphasis on removable connections and fittings and the distance between the pipeline and safety relevant installations of the Seveso site. During this survey it will also be evaluated if the pipelines are considered as a source of environmental danger in the risk assessment of the site. Finally there has to be a documentation of the risk assessment in the safety report. Depending on the answers of the operators there will be a specification and enforcement of the necessary measures. This Cologne concept for increasing the safety standards of Seveso sites in close vicinity to pipelines with inflammable gases has been adopted for the whole State of North Rhine Westphalia.

In addition to these measures a state wide extra inspection program on Seveso sites with special emphasize to the above mentioned constellations was launched. During this survey a further focal point was the human factor as it played an important role at the beginning of the ethylene leakage.



A B

Figure 8: Insulating flange with inserted nuts (A), maintenance-free welded insulating connector (B)

The State Environment Ministry of North-Rhine Westphalia has tasked the State Environment Protection Agency to advance the pipeline land register of the Cologne region to the whole area of the state. This register is based on a geographical information system and will be developed to a web application. So every civil protection authority and the ministries will be informed very quickly in case of catastrophes.

LESSONS LEARNT

We learned from the expert surveys that a leakage at the insulating flange of a high pressure gas pipeline could evolve during the maintenance work when the sequence of the tightening of the screws is not followed correctly or when the wrong torque is applied. In the case of pipelines with inflammable gases it is very important to prepare very detailed standard operation procedures and employ very skilled technicians to performance the maintenance work when the pipeline is under full pressure. A similar situation appeared a year before this accident as during maintenance work a leakage was detected. At that time the gas didn't ignite and the flange was renewed and used again after tests by an independent surveillance organisation. The best way to reduce the risk of leakages and subsequent fires is to use maintenance-free welded insulating connectors as shown in Figure 8(B).

Pipeline leakages with inflammable gases under high pressure tend to ignite even in the absence of external ignition sources. Removable constructions and fittings can be destroyed if they are arranged in the direct vicinity of potential leakage points. Fire supporting liquids like hydraulic oil can have dramatic effects on the development of the incident. So it is very important to arrange the valves, flanges and other fittings of the pipeline at a distance as long as possible from one another. If this is not possible it is highly recommended to use fire proof constructions of the fittings. Especially remote controlled hydraulic gate valves have to be considered under this perspective. These measures will be most important if a near distance to a high risk installation with inflammable substances is not avoidable.

Concerning Seveso sites pipelines have to be considered as a source of environmental danger. If a high risk pipeline is not taken into account in a proper way the risk assessment has to be adapted and documented in the safety report. Such an investigation may have subsequent impact on the requirements on removable connections, valves and other fittings of the pipeline in the direct vicinity of the Seveso site. A reduction of flange connections and fittings, fire proof constructions and a replacement of flange connections with inserted nuts by welded insulating connectors could be necessary. If possible, the distance between the pipeline and the Seveso site should be increased, as it is realized here.

Operators of Seveso sites and operators of nearby pipelines should exchange safety relevant information especially in the case of a change of the arrangement or the building of new pipelines. The same is valid for competent authorities who are responsible for the surveillance of Seveso sites and pipelines. Article 8 of the Seveso II directive (see below) should be applied in a similar way.

Article 8: Domino effect *(Seveso II directive)*

1. Member States shall ensure that the competent authority, using the information received from the operators in compliance with Articles 6 and 9, identifies establishments or groups of establishments where the likelihood and the possibility or consequences of a major accident may be increased because of the location and the proximity of such establishments, and their inventories of dangerous substances.

2. Member States must ensure that in the case of the establishments thus identified:

a. *suitable information is exchanged in an appropriate manner to enable these establishments to take account of the nature and extent of the overall hazard of a major accident in their major accident prevention policies, safety management systems, safety reports and internal emergency plans;*

b. *provision is made for cooperation in informing the public and in supplying information to the competent authority for the preparation of external emergency plans.*

Gas pipelines are not included in the Seveso II directive and there are no other European laws for this kind of installations. In Germany different directives for gas pipelines are in force (amongst others: Rohrfernleitungsverordnung, Gashochdrucksleitungsverordnung) with different requirements on construction and operation of these installations. There are also different competent authorities in charge of surveillance of the different kinds of pipelines. The maximum requirements concerning permission and inspections are demanded by the Rohrfernleitungsverordnung (pipeline directive). But ethylene pipelines lie in the jurisdiction of the Gashochdruckleitungsverordnung (directive for gas pipelines under high pressure) which only requires an announcement of new pipelines to the competent authority and inspections by approved private surveillance organisations. A change of these kinds of pipelines to the regime of the pipeline directive is highly recommended, as under this regime requirements similar to the Seveso directive are applied. Because of the threats of a leakage and the potential domino effect in combination with a near by Seveso site it is also recommended to incorporate gas pipelines in the next amendment of the Seveso II directive.

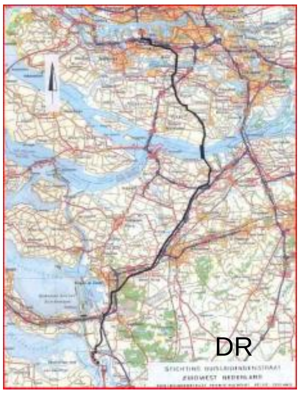
Leakage of a hydrogen-pipeline due to an inadequate inspection philosophy

12 October 2007

Binnenmaas (South Holland)
The Netherlands

Leak
Pipeline
Hydrogen
Cathodic Protection
Stressing factors
Inspection

THE FACILITIES INVOLVED



The site:

The Netherlands Pipeline Corridor (location of the accident: 300 metres from the village of Heinenoord (municipality of Binnenmaas) in the province of South Holland.

The involved unit:

A pipeline, transporting pressurized hydrogen gas (75 bar, 6 inch, steel) from Antwerp (Belgium) to Rotterdam (the Netherlands). The leakage occurred at a location at which the pipeline entered a building and contained a "CP coupling" (a device to interrupt the cathodic protection).

THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

The accident:

The investigation, as carried out by the Inspectorate of the Ministry for the Environment, has provided evidence that an underground pipeline, in which hydrogen gas is transported, developed a leak resulting in an escape of hydrogen gas. The leakage lasted for at least several hours but it can not be excluded that the leakage started weeks or even months prior to the discovery of the leak.

The leak occurred at a specific "weak spot" in the pipeline in which tensions could mount, resulting in the partial failure of a so-called "CP coupling".

The escaping hydrogen gas was ignited on the 12th October 2007 by welding activities which at that time were taking place in the vicinity of the leak as part of a construction project to add another pipeline in the corridor. The ignition resulted in a small fire on top of the soil covering several existing pipelines transporting several types of gases.

Because of the fact that at the start of the accident it was unclear what the nature of the escaping gas was several precautionary measures were taken by the police and the fire brigade. The inhabitants of the village nearby were advised to stay indoors for about three hours. Busy traffic on a nearby waterway to and from the Rotterdam harbour area was halted for several hours. After the conclusion that it was a hydrogen release and fire restrictions were lifted.

Although the transport of hazardous substances by pipeline along the route of the pipeline corridor is considered to be a safe means of transport, and the management of the pipeline corridor is meticulous, deficiencies in that management have been identified, mainly in the way supervision is carried out during construction activities in the corridor.

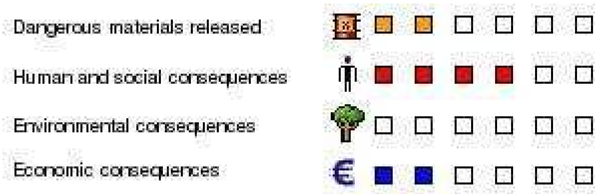
Consequences of the accident:

Given the fact that hydrogen gas is not toxic, and that a limited gas escape and fire were concerned, there has been no imminent danger to people living nearby.

Nevertheless, the incident has been classified as serious, because the gas escape could have been more extensive, and other transport pipelines that were lying nearby might have developed leaks for the same reason, which might have caused the release of poisonous gases.

The European scale of industrial accidents

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



Dangerous materials: At least 8.4 kilograms of hydrogen have escaped during the period at which the leakage was noticed, which lasted about 7 hours. Maybe the leakage has started even weeks of months earlier. It has not been possible to identify the start of the leakage suggesting that the amount of hydrogen released is probably in excess of 50 kilograms (Seveso threshold between 0.1% and 1% - Parameter Q1).

Human and social consequences :All inhabitants of the village of Heinenoord (3 400 people) were advised to stay indoors during 2.45 hours. ('Parameter H7')

Environmental damage: None because of the nature of the escaping hydrogen.

Economical damage: No serious estimate about the cost of the property damage has been made by anyone but the damage can be estimates at least 1 million Euros. ('Parameter €16')

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

THE ORIGIN, CAUSES AND CIRCUMSTANCES SURROUNDING THE ACCIDENT

The leakage was caused by a mix of several tension factors executed on the hydrogen pipeline. The predominant stressing factor was the gradual settlement of the pipeline and the earth surrounding it. The settlement took place over a time span of several years and resulted in the bending of the pipeline at a spot where the pipeline got stuck on a fixed structure, e.g. a feed through in which the pipeline enters a building. The bending forces caused tensions on the CP coupling nearby in the pipeline, which eventually started to leak.

Other stressing factors that might have contributed to the occurrence of the accident were unallowed heavy traffic and the placement of heavy equipment on the soil covering the pipeline.

The investigation has identified at least four supervising bodies that in some way or another were responsible for inspections with regard to the safety of the pipelines in the corridor. It were inspectors from the foundation, inspectors from the separate pipeline owners, inspectors from the consortium that carried out the construction works when the accident occurred and last but not least a notified body that was hired to inspect safety aspects of the construction of the new pipeline.

The Inspectorate of the Ministry for the Environment concluded that these inspection activities were not well coordinated and that they resulted in a situation in which inspectors did not feel responsible for overall safety. The inspectors all assumed that “the other inspection bodies” would do the inspections they did not do.

The accident has caused a lot of concern under the people living nearby the pipeline corridor and generated discussions in Dutch parliament and the local counsel of Binnenmaas.

ACTIONS TAKEN

Immediate actions: Repairing the pipeline, checking pipelines with similar constructions and tightening supervision during activities in the pipeline corridor.

Long term actions: Revising technical and procedural safeguards against the stressing of pipelines.

LESSONS LEARNT

Specific lessons (mostly of a technical nature):

- Criteria had to be established for the quality of CP couplings in pipelines and the installation and maintenance conditions associated with them in order to safeguard that the couplings are not exposed to any type of stress during their operational lifetime.
- Policies with regard to the measurement and interpretation of ground settlement had to be reassessed.
- A strict surveillance policy had to be developed to prevent infringements on rules regulating activities on top of pipelines in order to prevent the possible damage of these pipelines.

General lesson (of a organisational nature):

- An abundant series of supervisors and inspectors on a project does not necessarily mean that the essential requirements to safeguard a safe environment are met. On the contrary, one might conclude.
- All parties involved in the management of the pipeline corridor (the management of the foundation as well as all individual pipeline operators) had to redefine supervision and inspection policies in order to get a clear division between each other’s tasks and responsibilities, particularly during construction activities in the pipeline corridor. The additional supervisory role of external parties, like “notified bodies” and “independent supervisors” had to be included in this survey of responsibilities.

Explosion during a cupola drop inside a foundry

15 May 2006

Vivier-Au-Court (Ardennes)

France

Explosion
Metallurgy
Cupola furnace
Cupola drop
Molten residue
Water (in reaction)
Process (control)
Organization

THE FACILITIES INVOLVED

The site:

This foundry, located in the middle of the town of Vivier-au-Court in France's Ardennes department and in operation since 1929, is specialised in manufacturing cast iron parts used in the automobile industry, the building industry, heating installations, mechanical industry, farming etc.

The site employs a staff of 258 and belongs to a family-owned company that comprises six foundries and generated a turnover on the order of € 95 million in 2005.

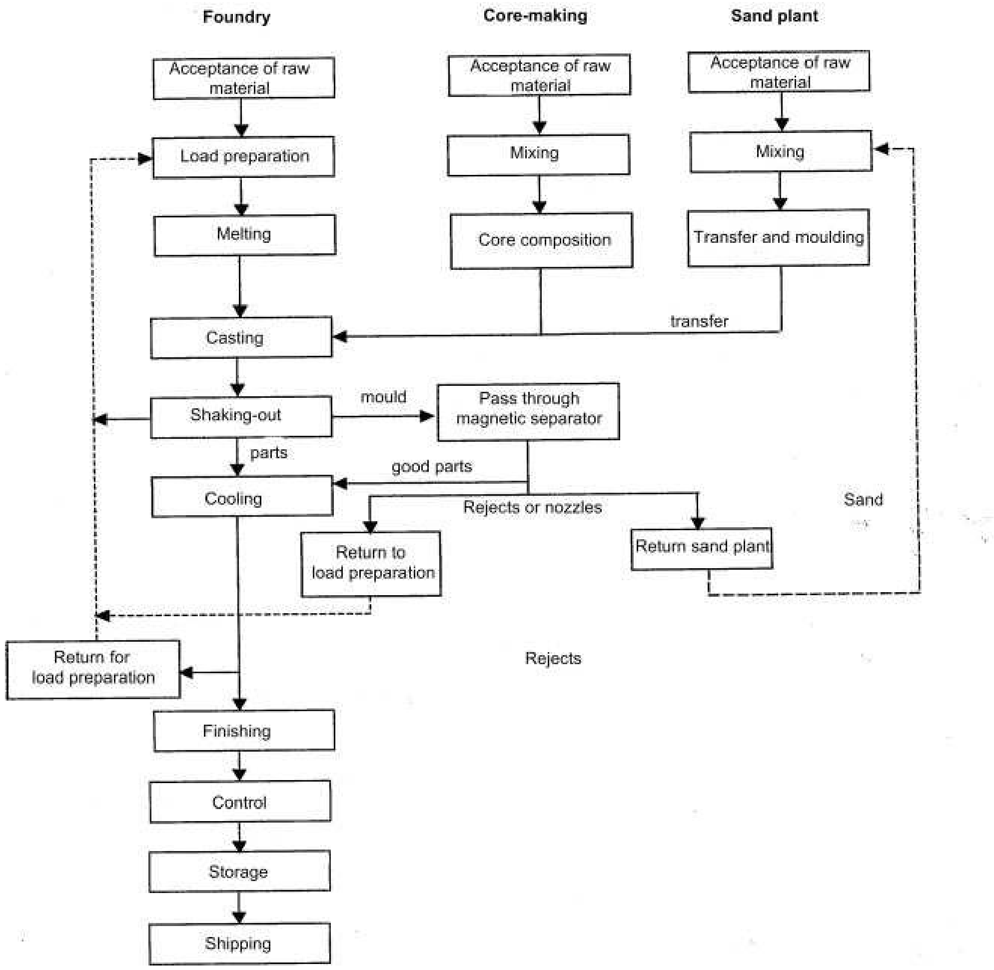
On an annual basis, the foundry produces approximately 25,000 tonnes of grey cast iron and 15,000 tonnes of spheroidal graphite (SG) cast iron.

Grey cast iron is produced using a cupola furnace, while the SG cast iron process involves electric ovens.

The installations requiring authorisation were addressed in an administrative review, via prefectural order issued on August 18, 2008 and superseding the previous order dated June 2, 1994. This latest administrative ruling is compliant with the IPPC Directive and incorporates the new set of melting tools.

Site entrance (source: operator)

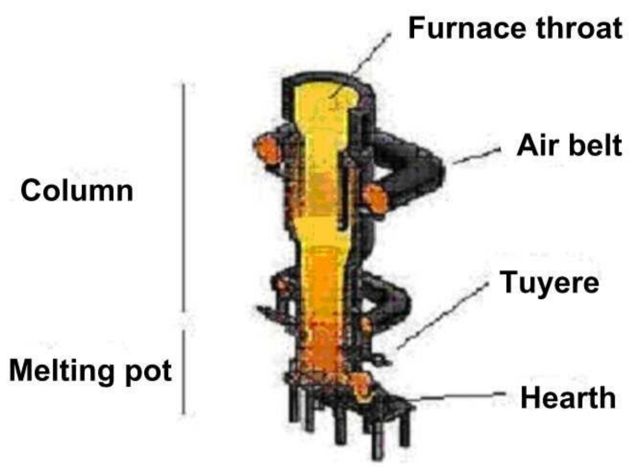
A useful schematic diagram of the plant's manufacturing process is shown below:



The involved unit:

The melting workshop involved in this accident comprises among other equipment two cupola furnaces each with a maximum production capacity of 150 tonnes/day. These furnaces are supplied with coke and operate in alternation every other day for periods extending at most 16 hours.


Cupola (source: operator)



Cupola operations (source: *Bref* Foundry)

The various manufacturing stages include:

Stage	***Operational details***
Load preparation	Mixing of alloy component elements Transfer onto the furnace loading platform
Cast iron melting	Introduction of load via a bridge crane / skip Melting of the load in either the cupola furnace or an induction furnace Slagging (manual removal of impurities)
Discharge	Emptying of ovens or cupola furnaces using a ladle
SG processing	Introduction of an alloy (iron-silicon-magnesium) in molten cast iron
Casting	Casting in the moulding machine: - mould installation - sand filling - compression and formation of the sand mould - manual or automatic ladle casting
Cupola drop	**Discharge (once a day) from the cupola furnace bottom of molten residue (slag, cast iron, coke) into a heat-resistant skip**
Shake-out	Separation of the parts and sand moulds using a vibrating belt
Finishing	Mechanical treatment of parts: shot-blasting, grinding, heat treatment

THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

The accident:

An explosion occurred on Monday, May 15, 2006 at 6:30 pm, corresponding to the time of a cupola drop. The door located on the lower section of the cupola furnace was opened as for discharging the products remaining once the melting process was completed (incandescent coke, cast iron and slag residue) into a skip set up below the furnace. This metallic receptacle was lined with refractory cement.

An employee was positioned at a distance of 10 metres from the skip as a precaution to control any eventual fire outbreak.

The explosion took place at the time the molten residue was being dropped into the skip.

Cupola zone (source: site operator)

Skip used for cupola drop (source: operator)

Consequences of the accident:

Pieces of coke, cast iron and slag were projected inside the building. Emergency response units were notified and company personnel evacuated and then reassembled at premises located beyond the danger zone. External fire-fighters secured the damaged zone and oversaw the safe evacuation of all personnel.

The employee positioned 10 metres from the cupola drop zone was burned on the face and arms by the hot air blast of the explosion, necessitating a 4-day hospital stay; a second employee, found in a state of shock and treated onsite by the fire-fighting crew, was able to report for work two days hence.

The roof was destroyed over a 30 m² area; property damage costs were estimated by the site operator at 10,000 euros. Technical equipment and installation of the cupola furnace sustained no damage whatsoever; production could thereby resume the next day according to the regular schedule and under normal operating conditions.

The explosion blast caused dust that had accumulated on the metal frame of the building to fall to the floor. The zone damaged by the explosion was quickly cleaned. No rainfall was recorded at the time of this event, which served to avoid any runoff of contaminated stormwater to the soil. Moreover, no fire extinction water needed to be sprayed.

The European scale of industrial accidents

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

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

Level 1 of the "Dangerous materials released" index characterises the explosion that occurred (parameter Q2: quantity of explosive substances in TNT equivalent less than 100 kg).

The hospitalisation of an employee for more than 24 hrs explains the level 1 ascribed to the "Human and social consequences" index (parameter H4).

The cost of property damage in the company did not reach the level 1 threshold of the "Economic consequences" index (parameter €15); production losses on the other hand were not quantified or notified to the inspection authorities for classified facilities, which prevented characterising the parameter €16.

THE ORIGIN, CAUSES AND CIRCUMSTANCES SURROUNDING THE ACCIDENT

Given the level of installation knowledge and accident history for this type of equipment, the most frequent accidents consist of projections of molten metal due to either the contact between water and metal or the formation of a gas accumulation (CO / H_2). Such projections are capable of initiating a fire.

The water / molten metal reaction was the cause of this accident: the refractory cement lining the residue recovery skip was only set into place the same morning and the drying period proved insufficient. This skip, intended to serve as a receptacle for residue after melting, contained residual humidity. Water entering into contact with molten residue either triggers a vapour explosion (purely physical phenomenon) or leads to the formation and subsequent explosion of hydrogen or CO (chemical redox phenomenon).

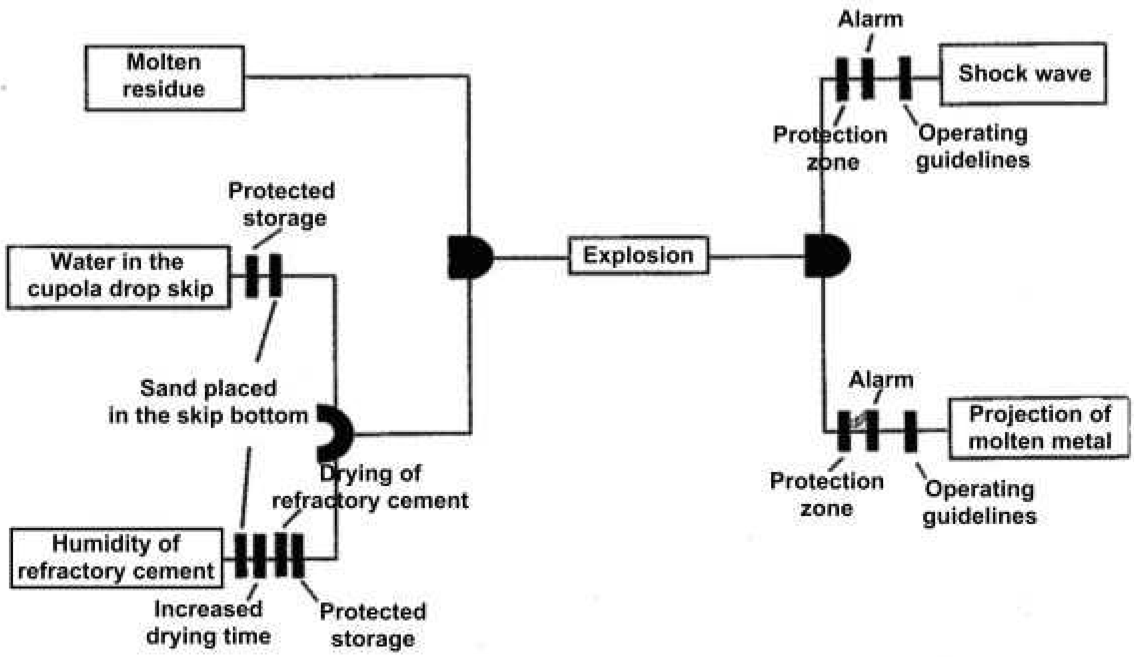
ACTIONS TAKEN

Following the accident, an extraordinary meeting of the Committee for hygiene, safety and working conditions (CHSCT) was convened; findings were delivered in a report dated May 29, 2006 confirming the accident causes cited above.

The facility operator also updated the Safety Report as part of the permit application file, which was on the verge of being submitted to the Prefecture.

LESSONS LEARNT

Several technical and organisational measures were adopted in order to reduce the probability that such an accident repeats as well as to remedy the effects of an eventual accident. The following identification of technical safety barriers for prevention and protection was performed as part of the Safety Report update:



→ the technical measures were primarily focused on removing humidity in the metal skip, for the purpose of eliminating the risk of explosion due to contact between residue after melting (cast iron residue) and water, i.e.:

- ✓ acquisition of three skips so as to better manage equipment utilisation and ensure sufficient drying time for the refractory cement (36 hrs). Skip labelling was also introduced;
- ✓ storage of this containment capacity at a site protected from water;
- ✓ drying of the skip intended for daily cupola drop using a gas burner;
- ✓ placement of a bed of black foundry sand at the bottom of the skip to both eliminate all eventual traces of residual humidity and provide additional protection at the skip bottom.

→ organisational measures to enable limiting the number of individuals working in the hazardous (so-called "protection") zone where the cupola drop takes place:

- ✓ clearly identifying the protection zone by demarcating a boundary around the cupola furnace;
- ✓ installing a sound alarm designed to notify personnel during the cupola drop period;
- ✓ designating a cupola drop supervisor with the responsibility to trip the alarm and ensure that the protection zone is always free of any unprotected or unauthorised individuals;
- ✓ revising operating guidelines and appointing a Head of Operations, who among other things is to verify that the refractory cement lining the skip is well dried;
- ✓ updating, in conjunction with employees, the list of individual protective gear (by occupation or by workstation) to be worn: helmet with a face shield, safety jacket and aluminised gloves, and appropriate pants;

- ✓ scheduling of evacuation drills to allow personnel to become acquainted with the alarm system and other onsite safety features.

Delimitation of the protection zone (source: operator)

This set of measures has made it possible to include the given accident scenario within the new Safety Report as being tolerable with a probable event of medium severity.

Fire and explosion of ammonia synthesis gas

1st June 2006

Billingham

United Kingdom

Ammonia
Joints
Piping
Valve
Organisation/Maintenance

THE FACILITIES INVOLVED

The site:

The plant primarily produces ammonium nitrate-based fertilizers; part of this process entails synthesising ammonia. The particular unit is located within the Billingham industrial complex, a site that falls under jurisdiction of the *SEVESO* directive for hazardous installations. The closest residences lie at a distance of 500 m from the scene of the accident.

The involved unit:

The unit involved in this accident was the ammonia synthesis column.

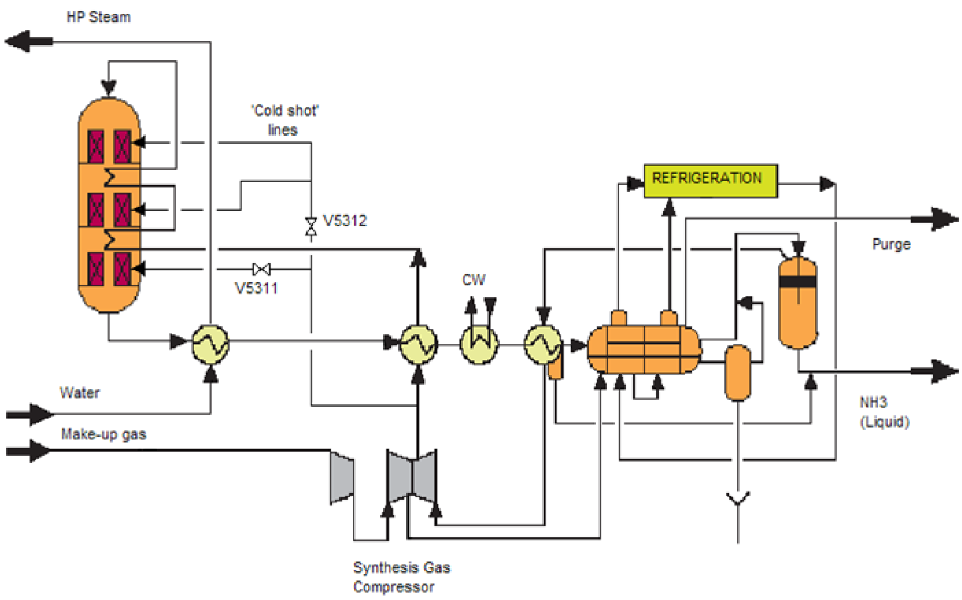


Figure 1 - Ammonia Synthesis

THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

The accident:

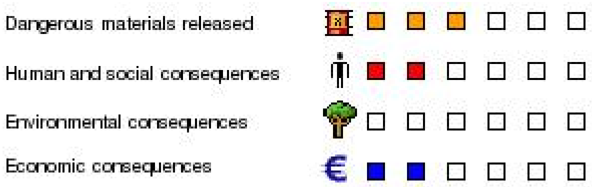
Around midnight on the night of Wednesday June 1st, 2008, an extremely flammable leak of a so-called "synthesis gas", containing primarily hydrogen, occurred on valve V5312 within the ammonia synthesis column.
The gas, released at a pressure of 220 bar and a temperature of 120℃, ignited spontaneously, forming two flame cones directed along the pipe connected to the valve. The pipe could not resist the heat from these flames; and under such internal pressure, it burst in freeing its contents, which in turn exploded. The quantity of gas released during the accident was estimated at 1.45 tonnes. The gas continued to burn for more than two hours, given the quantities found at the site when the fire broke out.

The consequences of this accident however remained confined to the zone adjacent to the valve.

The accident happened during a period of limited activity, with just one team of four technicians and a supervisor present in the unit. When the fire was detected, two technicians left the control room to isolate the valve. The pipe actually burst while they were still performing this operation. The pressure surge generated by the explosion was strong enough to knock one of them to the ground and send debris flying, a piece of which struck and slightly injured the other technician.

The European scale of industrial accidents:

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



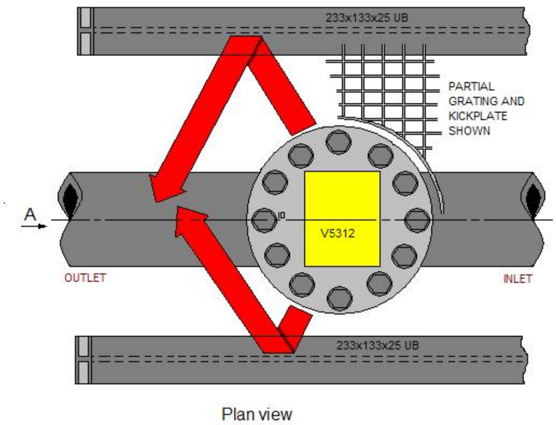
The parameters composing these indices and their corresponding rating protocol are available from the following Website: **http://www.aria.developpement-durable.gouv.fr**

A level of 3 assigned to the "Hazardous materials released" index characterises the resulting gas discharge; 1.45 tonnes of synthesis gas were freed and since hydrogen represents 75% of the gas composition, this incident was the equivalent of losing approximately 1.2 tonnes of hydrogen, i.e. a tier in excess of 2% of the *Seveso* cap for extremely flammable gasses and liquids.

The number of slightly injured personnel explains the level 1 rating reached by the index relative to human and social consequences (parameter H5: 2 slight injuries).
The company estimated the economic consequences of the accident to be as follows: 6-week production loss, and the works required to restore the damaged unit to operability - in the vicinity of £2 million, i.e. approx. €3.3 million.

THE ORIGIN, CAUSES AND CIRCUMSTANCES SURROUNDING THE ACCIDENT

This accident was caused by a gas leak on the joint between the body and cap of a shut-off valve [V5312] on a pipe transporting synthesis gas. The valve, in the open position, was operating at full flow. The seal between the two parts, held together by 12 bolts, was applied to a metal-on-metal contact. Inspection of the valve indicated that gas had leaked in two spots prior to ignition, meaning that two distinct flames were produced.



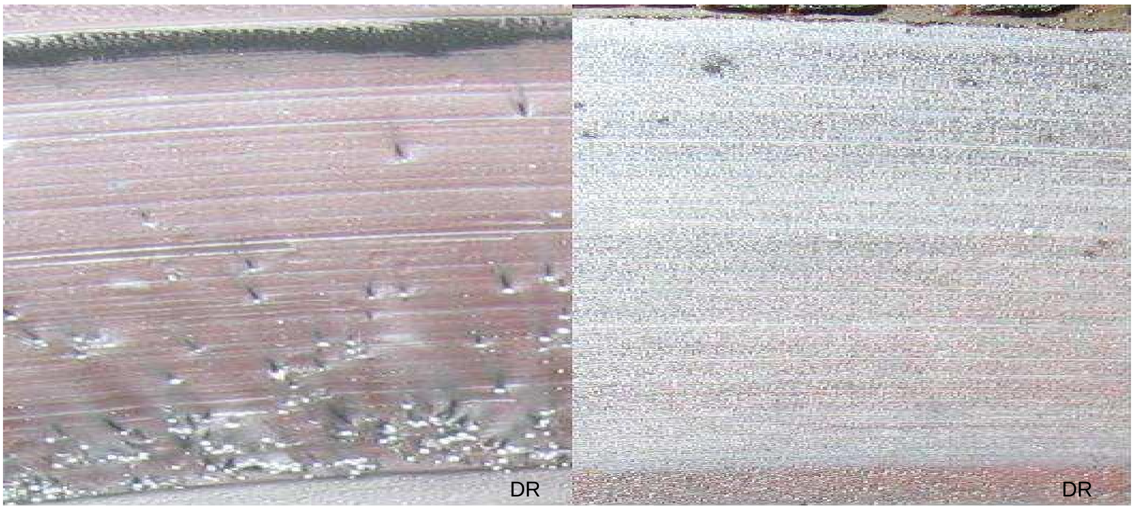
Given the layout of the structure's metal frame, one of the flames actually "ricocheted" off the side and reached the pipe on the outflow side of the valve, causing it to heat for some ten to fifteen minutes, before bursting open over a full metre and releasing gas at a pressure of 150 bar.

The valve had been operational since 1975. In October 2002, as part of a maintenance procedure, the cap [upper part of the valve] separated from the body [lower part] and reached some of the valve's internal parts. This procedure was performed by a subcontractor.

Several anomalies were observed:

- inadequate clamping of nuts, the subcontracted firm did not follow any pre-established set of procedures or specifications in conducting this operation;
- a metallurgical examination of the valve seal surfaces revealed a degraded surface condition: a sizeable lateral surface groove, presence of particles (though below manufacturer's standards). Also noteworthy was that the particles were apparently of a shape and composition analogous to those of shot blasting material used to clean metal surfaces.

A comparison of seal surfaces on the valve that caused the accident with those of an identically-designed valve clearly highlights the particles responsible for surface defects: the surface roughness of this deficient valve was twice that of a similar valve (see photos below).



The investigation carried out by the HSE unit exposed the following:

- The operator did not consider the valve to be a critical element for plant safety.
- The subcontractor selection process seems to have been based on price criteria rather than the level of competence and experience demonstrated in maintaining this type of valve.
- The operator provided no technical information concerning the valve to the subcontractor.
- The subcontractor was uninformed of valve characteristics and did not keep any kind of log for monitoring the operations already completed.
- The operator did not inspect work performed on the valve.
- The particles detected on seal surfaces were similar to materials used when shot-blasting metal surfaces. Their origin remains unknown but were undoubtedly deposited prior to the maintenance work of 2002.
- No log was kept regarding the amount of torque applied to the joint fastening bolts. It is therefore impossible to determine whether the valve had been lifted with the right clamping force.

ACTIONS TAKEN

The conclusions of this investigation were discussed with the operator and subcontractor assigned the valve repair job. Corrective measures were laid out with the objective of improving plant procedures.

LESSONS LEARNT

Maintenance work at installations generates specific risks that need to be analysed in order to define the best-suited means of prevention. Such an analysis proves even more essential given that maintenance operations are most often outsourced to subcontractors. The operator must pay careful attention to the choice of contracted parties by ensuring that they have the requisite level of competence, training and qualifications to successfully undertake the planned works. A risk management effort on the part of the site operator is necessary and implies the following: preliminary risk analysis, qualification procedure for all subcontracted entities, preparation of the maintenance intervention (detailed description of works to be performed, equipment specifications, documentation, procedural information, etc.), traceability of the works undertaken, and acceptance conditions by the operator.

A similar accident occurred in GONFREVILLE-L'ORCHER on April 24, 2006: During start-up of the ammonia production unit at a chemical plant, a synthesis gas leak ignited on a flange immediately adjacent to the synthesis reactor. The tightening torques used to bolt this flange were found to be the cause of the accident (ARIA 32174*).

* A summary of this accident is available at: www.aria.developppement-durable.gouv.fr

Chlorine leak during connection of a rail tanker to prepare for an unloading operation
14 February 2008
Château Arnoux - Saint Auban (Alpes-de-Haute-Provence) France

Chlorine
Joints
Unloading
Procedures
Training
Facility ageing
Spare parts

THE FACILITIES INVOLVED

The site:

The plant, classified as an upper-tier *Seveso* (or AS), is engaged in the following activities:

- fabrication of PVC in the form of either pastes - as a micro-suspension (used for floor coverings, capsule packaging, coated fabrics, etc.) or microbeads - copolymers (used for floor coverings, food or other packaging, vinyl records),
- production of specific chlorine solvents T111 trichloroethane (the only European manufacturer to produce this raw material, which is used at the Pierre Bénite plant),
- incineration of chlorine residue, especially with a high PCB load,
- occasional production of soda and hydrochloric acid.

This site is currently undergoing a major activity reorganisation.

The involved unit:

The material transfer station, where the incident occurred, is located in the northern part of the plant (within the enclosure of the former mercury electrolysis operation). This station was designed to supply site storage areas during the transitional phase underway between shutdown of the mercury electrolysis process (2005) and start-up of the membrane electrolysis process (2009). At the present time, the transfer station is shut down and being dismantled.

THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

The accident:

On Thursday, February 14, around mid-morning (9:28 am), during an operation to hook up a rail tanker containing chlorine for the purpose of proceeding with unloading, a chlorine leak occurred at the level of the joint between the flanges of one of the connections.

One of the technicians closed the valves (cutting off the compressed air) after 30 seconds and then triggered the alarm and water curtains, all within 3 minutes from the time the leak began.

Consequences of the accident:

The leak, which lasted a total of 30 seconds, released some 11 kg of chlorine into the atmosphere, thus creating a cloud on the ground covering approximately 50 m by 10 m. This cloud was partially dispersed by the water curtains.

Four members of the personnel (the 3 technicians and a contractor with an external firm) became slightly intoxicated, yet were still able to return home the same evening.

Since the flanges were not damaged, the rail tanker was normally unloaded during the afternoon

The European scale of industrial accidents:

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

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

Level 1 of the index entitled "Hazardous material released" characterises the toxic gas discharge that occurred (parameter Q1: quantity of the substance actually discharged in comparison with "*Seveso*" threshold: 11 kg of chlorine).

The number of slightly intoxicated victims explains the level 1 reached by the index relative to human and social consequences (parameter H5: 4 slightly injured).

Moreover, since the property damage and operating losses had not been quantified by the site operator (parameters €15 and €16), the index relative to economic consequences could not be rated.

THE ORIGIN, CAUSES AND CIRCUMSTANCES SURROUNDING THE ACCIDENT

The origin of this accident can be traced back to a rupture of the transfer arm flange joint during a seal leak test.

Probable causes of the accident are:

- use of two 2-mm joints instead of one 4-mm joint,
- poor clamping of the sealing ring between the two liquid phase flanges,
- a seal leak test performed in an atmosphere containing chlorine and not nitrogen.

The use of two 2-mm joints instead of one 4-mm joint was due to the preferred product being out of stock. The technician responsible for performing this clamping operation was attending a training class under the supervision of the other two technicians, both of whom were not located nearby given the cluttered workstation configuration. The clamping operation using the bolting machine was unfamiliar. The technicians were not equipped with self-breathing apparatuses because the air compressor package only contained 2 outlets for 3 technicians. The water curtains were not automatically deployed; furthermore, technical staff from external companies was present in the sector during operations.

ACTIONS TAKEN

Subsequent to this accident, the plant operator introduced a number of measures, namely:

- a safety stock of the 4-mm thick joints was constituted, and a directive was issued prohibiting this type of operation from proceeding in the absence of the dedicated joint;
- a special training session devoted to assembling and clamping this type of joint onto test benches, with technician certification;
- reminder of the need for strict application of the guidelines both on wearing the self-breathing apparatus when opening circuits containing toxic products and on the proper procedure to follow when the number of breathing apparatuses falls short of the number of individuals present in the specific sector;
- recall of the strict respect of authorisations granted to external companies by plant managerial staff. As a case in point, the station manager authorised the intervention of external personnel even though the procedures specifically prohibited all such works from being carried out during any chlorine transfer operation;

- recall of the protocol for notifying the company responsible for site safety (failure to activate the general siren for this level 2 alert was observed, though the information had been correctly transmitted);
- a reassignment of the in-plant gathering rooms along with a reminder of the proper steps to follow in the event an alarm is sounded; plus the scheduling of specific drills in order to raise personnel awareness since during the accident, some disused rooms were not notified and a number of technicians did not obey the guidelines for how the staff should assemble.

LESSONS LEARNT

A site comprising older installations or undergoing reorganisation is vulnerable to a sequence of accidental or risky situations due to deteriorated operating conditions or a loss of knowledge of trade practices on the part of technical staff. Such situations do not just concern ageing facilities, but also pertain to respecting procedures and guidelines that may have been forgotten or circumvented over time. Throughout the life of the facility and especially when conditions are deteriorated (e.g. a site undergoing reconversion), special attention must be paid to respecting the safety management system.

Perforation of a gaseous fuel distribution pipe

22 December 2007

Noisy-le-Sec (Seine-Saint-Denis)

France

Piping / distribution
Natural gas
Leak
Explosion
Contracted works
Victims
Property damage
Declaration / "DICT"

THE FACILITIES INVOLVED

The site:

In the town of Noisy-le-Sec (Seine-Saint-Denis Department north of Paris), municipal gas supply is distributed by means of a public pipe network. The particular installation involved in this accident is the network supplying a group of buildings in the city centre within a so-called "private" district (i.e. non-subsidised housing).

Source: DRIRE Environment Agency (Paris Region)

THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

The accident:

On December 22, 2007 within a private residence composed of several housing blocks, a public works contractor was drilling boreholes in order to evaluate site subsoil by means of extracting core samples from deeper strata.

While drilling the first metre of one of the final sampling boreholes, located 3 metres in front of the entrance to a main stairwell, the two foremen supervising the works detected a gas smell and then noticed a gas jet escaping.

They immediately shut off the boring machine to alert emergency services (fire-fighters, police); the time was 8:48 am. Gas company technicians received an initial call at 9:00 am, but for an erroneous address in the neighbouring city of Bobigny; the second call to the gas response unit, five minutes later, provided the correct address.

The gas supply pipe was punctured by the drilling, which created a 63-mm diameter hole, and then projected upward into a 100-mm casing from a previous pipe installation on the same site.

Once on the scene, police and fire-fighters evacuated the entire building, beginning with the central portion. At 9:30 am, the gas technicians arrived onsite.

By around 9:35 or 9:40 am, police and fire-fighters had evacuated all individuals potentially exposed to risk.

The first explosion happened right about 9:45, in other words just 5 or 10 minutes following the building's full evacuation. A number of fire-fighters and police officers were injured, while the on-call technician was able to find cover in time.

A second explosion occurred at approximately 9:53 am, and this time the gas technician was hurt by the shockwave.

By 10:52 am, the residential zone was considered completely secured, from the standpoint of gas explosion risk, by the rescue team.

Agents from the local DRIRE Office, notified of the accident at around 11:00 am, reached the scene by 1:00 pm, although access at the time to the damaged zone was reserved exclusively for police and fire-fighting personnel. Even those agents assigned to monitor the gas distribution pipe system were denied access to the explosion site.

Consequences of the accident:

It must be emphasised that the building collapsed just 5 or 10 minutes after being completely evacuated.

Fire-fighters were heavily challenged to extinguish the fire that broke out following the two explosions. Of the entire housing block, both the central and right parts were totally levelled and burned. All building residents had to be relocated to alternative housing.

The window panes of buildings lying just opposite as well as those of a neighbouring school (empty at the time) were shattered.

Source: DRIRE Agency, Paris Region

The European scale of industrial accidents

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

Given the inability to estimate the quantity of gas released both before and after the explosions, the "hazardous materials released" index was recorded, by default, as 1 due to the two explosions produced (parameter Q2).

The eight individuals injured among fire-fighters, police officers and gas service employees explain why a level 2 was ascribed to the "human and social consequences" indicator.

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

THE ORIGIN, CAUSES AND CIRCUMSTANCES SURROUNDING THE ACCIDENT

Once the pipe had been punctured, some of the gas escaped in the form of a gas jet, while the remaining amount of gas perhaps migrated and wound up accumulating in the basement of the nearby building. The ignition source of the gas pocket or cloud could not be identified.

On the same day, during the investigation conducted by both the police and DRIRE agents, the onsite work crew was unable to provide drawings that could potentially correspond to the DICT (notice of intent to begin works). The search undertaken by the gas company's technical department to track the DICT notice also proved fruitless.

The public works contractor was therefore drilling boreholes without any detailed drawings of the gas distribution network, information that would have been provided in the DICT. The contractor indicated to the authorities that for the prior boreholes on this site, they had proceeded by means of manual boring, but for the last one such preliminary boring had not been performed by the crew, undoubtedly in order to save time. Let's recall that this drilling campaign was being conducted on Saturday, December 22.

A legal investigation is currently underway.

SUBSEQUENT TECHNICAL ACTIONS

The valve supplying the accident zone was closed, which caused gas supply to be shut off to 172 residential customers.

Until the end of the evening of the 22^{nd}, fire-fighters were still spraying the rubble. The wide safety perimeter was maintained for over 24 hours. Due to the legal investigation and while waiting for large amounts of debris to be removed, a smaller perimeter was set up.

Over the next few days, DRIRE agents contacted managers of the public works contractor, who were able to confirm the nonexistence of a DICT notice. A correspondence dated December 27, 2007 summarising the situation along with data collected was sent by DRIRE to the contractor.

The families evacuated from the building were relocated by the City of Noisy-le-Sec in temporary housing units reserved for new arrivals for an indefinite period.

LESSONS LEARNT

The Noisy-le-Sec accident lies within a sequence of serious accidents that arose between the end of 2007 and beginning of 2008 on national gas company infrastructure. Over this same period, other accidents occurred in the cities of Bondy, Niort and Lyon, accounting for a total (including Noisy-le-Sec) of 100 victims, including 2 deaths. This heavy human toll is the most visible outcome of a much higher number of serious gas leaks (6,000 a year in France), as a result of works performed adjacent to structures.

In this context, France's Ministry of Sustainable Development has undertaken, in conjunction with other involved Ministries (mainly Interior and Labour), a major reform of Decree No. 91-1147, adopted October 14, 1991 relative to the safety of building works conducted in the vicinity of all types of utility networks, especially gas distribution and hazardous materials transport networks. This reform, whose content and implementation protocol are still under review and discussion, should be ready for application in 2010. These efforts are aimed at introducing the following improvements:

1. Creation of a single national unit, to replace a mission currently backed by the municipalities: Positioned at the interface between third-party contractors and utility network operators, such a single unit would be assigned to keep a record of contact details for all network operators working in France, plus drawings of the zones where their networks actually run. Based on information recorded and continuously updated, this unit will provide via an Internet platform to all authorised contractors (who must furnish the unit with footprint drawings of any planned worksite) an exhaustive and fully reliable list of network operators responsible for servicing the particular zone or its immediate vicinity. Contractors would thus be able to directly contact network operators potentially affected by the planned works and could then determine in concert with each of them the set of appropriate measures for executing works under the safest conditions.

2. Advanced training for utility network actors, and credentialing requirement: Statistical records reveal that accidents are not due solely to frequent lapses in notifying works projects, but also to unsuitable jobsite practices, particularly regarding the use of aggressive or poorly-managed techniques and a widespread misunderstanding of potential hazards. Both initial training and continuing education need to be defined, in association with the corresponding set of credentials. As an example, qualifications specific to driving public works vehicles (i.e. "CACES", French for Special Vehicle Driving Licence) will be completed by a specific module devoted to the safety measures anticipated for zones closest to utility networks. Similarly, contractors performing localisation measurements to improve network mapping or practicing emergency intervention will be required to complete special training and a certification procedure.

3. Development of an expanded observatory: Such an observatory is intended to compensate for the current lack of dialogue between actors and to introduce a tool for managing feedback on anomalies, incidents and accidents in order to institute a progress-oriented approach that involves all stakeholders. This expanded unit will rely heavily on the existing regional observatories, encompassing construction firms and network operators, and will extend to: local authorities, administrative agencies responsible for monitoring gas distribution pipelines, and contractors unfamiliar with the practice of filing work notices (agricultural sector, nurseries, landscape architects, sign setters, drillers, etc.). These observatories will also conduct campaigns to disseminate information and build awareness of applying regulations and employing best practices.

4. Other planned regulatory measures: Besides introducing a number of measures relative to the single, consolidated unit and training / credentialing (points 1 and 2 above), this regulatory reform will also focus on:

- heightened responsibility of project owners, especially through mandating that they conduct additional investigations whenever network localisation proves too imprecise,
- modernisation of both the works permitting and notification forms (DT, DICT),
- continuous reliability enhancement of network mapping thanks to geolocalisation measurements carried out during improvement work on existing networks and at the time of inspecting new networks,
- an optimal definition and dissemination of appropriate building techniques for the zone closest to the network layout,
- the potential to stop work in progress in the presence of a proven serious hazard relative to a network,
- preparation prior to commencing work of an accelerated intervention strategy in the event of network damage,
- penalties applicable in the case of rule violations.

Release of SO_2 from a cellulose factory caused by an electrical power failure.

16 August 2006

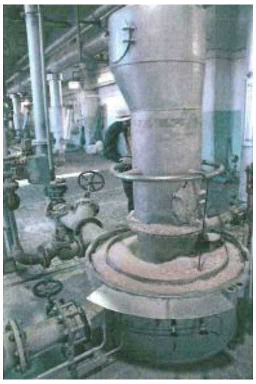
Germany

Realease
SO2
Electrical power failure
Alarm system
Modifications
Safety management system

THE FACILITIES INVOLVED

The facility involved in this incident is a cellulose manufacturer, producing cellulose by the sulphite-process in which wood chips are boiled in a cooking acid consisting of a combination of free sulphur acid and sulphur acid bound as magnesium bi-sulphite.

The unit involved was one of the reactors in which wood chips were treated with cooking acid.



Hubert Kerber, TÜV-Süd

THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

The accident:

The consequences of an electrical power failure at a cellulose manufacturer show the importance of understanding how particular processes and installations depend on specific infrastructure elements and utilities. This requires a systems-based approach to hazard identification.

The installation produced cellulose from wood chips by the sulphite process in which the wood chips are heated in a reactor containing sulphurous acid which is enriched with SO_2. (sulfur dioxide). The reactor was charged with wood chips at the top of the reactor. After charging the lid was closed, the acid added and the reactor heated. During the heat-up phase the lid of the reactor was kept sealed using water pressure maintained by an electric pump. Once sufficient pressure had been built up within the reactor the seal system could be switched over to "self-sealing" using the reactor pressure.

The incident occurred when a reactor was in the heat up phase and there was a complete power failure on the whole site. This meant that the water pressure could no longer be maintained and the seal of the reactor failed; this lead to a release of SO_2 into the cellulose boiler house. The release of SO_2 to the atmosphere was sufficient that it was noticed by a passing motorist who alarmed the police and fire brigade.

Fortunately the reactor was at sufficient pressure to maintain the seal under its own pressure and the actions of an employee to switch over to "self-sealing" mode reinstated the seal.

The investigation of the accident showed that there was a lack of awareness about how vulnerable the electrical power supply was to power-outages, and in particular that one failure could cascade through the whole system. It also showed the need to be aware of how infrastructure and utilities are linked together and that individual failures can lead to the breakdown of whole systems.

The consequences drawn from the accident are to modify the sealing system so that nitrogen is used to maintain the pressure. In addition the emergency planning should take account of the potential release from the cellulose reactors as previously only the SO_2- storage had been considered as a potential source of a SO_2 release. Generally improvements needed to be made in the company to improve the handling of hazardous incidents.

Consequences of the accident:

The failure of the reactor seal due to the electrical power failure led to the release of ca. 100 kg SO_2. No injuries were reported, There was no damage to property recorded, however the costs to the company of dealing with the incident were put at around € 170 000.

The European scale of industrial accidents

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

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

The "dangerous materials released" index is rated at 1 due to approximately 100 kg SO2 released (parameter Q1).

The accident had no human, environmental or economic consequences.

THE ORIGIN, CAUSES AND CIRCUMSTANCES SURROUNDING THE ACCIDENT

The causes of the accident lie in two areas: a) the electrical power supply and b) the means of maintaining the seal of the reactor.

a) Electrical power supply

The 110 kV power supply from the power supply company was transformed to 20 kV and transferred to the works' distribution bus via 5 earth cables in two channels (2 cables and 3 cables). The distribution bus was separated into a supply and a demand side, also it was divided into two stations corresponding to the two channels of 20 kV supply. Additional energy was produced by a number of steam turbine generators; two attached to Station1 and one attached to Station 2.

Under normal operating conditions both sides of the distribution bus were coupled and there was a balanced supply and demand situation. If the machines connected to Station 2 were not operational then the supply from the steam turbine attached to this station was supplied via the two (supply and demand) 20 kV busses to the machines connected to Station 1. However this meant that the meters for determining the power supplied by the power supply company (which were attached to the supply side of the bus in both station 1 and 2) gave false readings in favour of the energy supply company. Thus, under these operating conditions it was necessary to open the connection in the supply side between Stations 1 and 2.

Modifications and enlargement of the production machines on a large scale (e.g. 3 new 900 kW motors) had been carried out. On the day the power failure occurred production was running from Station 1. There was an increased demand on Station 2 due to the start-up processes taking place and the extremely large current demand for these very large units. This led to a rapid increase in demand and the triggering of the circuit breaker and the supply point for Station 2. This meant that the complete demand was placed on the supply point for Section 1. This demand could not be met and the circuit breaker was triggered, which meant that the supply from the power supply company was cut off. The company's own supply via the steam turbine generators then collapsed due to too low frequency and voltage, resulting in the whole facility being without power.

The preventative maintenance and the highly developed load shedding system, which could not react fast enough, were unable to prevent the total blackout.

The changes in the power demand due the enlargement of the facility were not considered within the management of change

b) Maintaining the seal of the reactor

The reactor was charged with wood chips at the top of the reactor. After charging the lid was closed, the acid added and the reactor heated. During the heat-up phase the lid of the reactor was kept sealed using water pressure. Once sufficient pressure had been built up within the reactor the seal system could be switched over to "self-sealing" using the reactor pressure.

The incident occurred when a reactor was in the heat up phase and there was a complete power failure on the whole site. This meant that the water pressure could no longer be maintained and the seal of the reactor failed; this lead to a release of SO_2 into the cellulose boiler house.

The method chosen for maintaining the seal in the heat-up phase was dependent on the electrical power-supply to drive the pumps which maintained the water-pressure. The possibility that the electrical power-supply could fail completely during the heat-up phase had not been considered. The interdependence of utilities for the safe operation of the process was beyond the scope of the hazard identification process.

ACTIONS TAKEN

An immediate decision was that the coupling between the supply busses for Stations 1 and 2 should remain closed. This no longer presented a metering problem as the metering was now carried out at a point not connected to the supply busses.

The method used to maintain the reactor seal was converted to be completely nitrogen based. A nitrogen generator with a storage tank was installed together with an additional gas bottle supply for the event of a technical defect or electrical power failure.

Modifications were also made to the alarm system to take account of a potential SO_2 release in the reactor hall. Previously to the event only SO_2 releases from the bulk storage of SO_2 had been considered. The procedures for notifying the emergency services in the event of a release were also improved.

The safety management system was also amended to take account of the experiences gained during this event.

LESSONS LEARNT

Utilities (water, gas, steam, electricity) may be highly interdependent. The failure of one of these, particularly electrical power may have knock on effects in other systems. Only a systematic approach to hazard identification together with an understanding of how the utility supplies actually function will enable an operator to identify the potential for any further consequences.

The reliability of the electrical power supply for facilities handling large quantities of hazardous substances is often not considered as a safety relevant aspect.

Modifications in one area of the facility may have consequences in quite separate parts of the site. Start-up of large equipment places extraordinary demands on the utilities and possibly other resources.

Release of hydrogen sulfide in a refinery with transboundary effects

2 September 2008

Antwerp

Belgium

Release
Refinery
Hydrogen sulfide
Power failure
Victims
Communication
Transboundary effects

THE FACILITIES INVOLVED

The site:

The plant at which the incident occurred is a refinery in Antwerp. It produces fuels like propane, butane. LPG, benzene, kerosene and gas oil, and chemical products like hexane, heptane, benzene, toluene and others.

The capacity of the refinery is 13.5 million tons a year.

The plant is situated at the eastern riverbank of the river Schelde to the north of Antwerp about 6 kilometers south of the border between Belgium and The Netherlands.

Electrical power is supplied tot the refinery by two 36 kV power lines.


DR

THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

The accident:

The morning of September the second, maintenance work was planned by the company that supplies the electrical power to the refinery. The two power lines had proved to be fragile and it was planned to replace the connections in both power lines. To that order one of the power lines was shut of at 11.56 am.

A plan to do this had been communicated beforehand, and it was tested that the remaining power supply would have enough capacity to transmit the necessary electrical power.

At 11.57, whilst maintenance work was being carried out at one of the two the electrical power supply lines, the remaining second supply line failed, thus rendering the refinery without electrical power supply.

At 11.57, start of the execution of the emergency plan, implying emergency shut down of the refinery, evacuating all not necessary personnel and retaining only the emergency staff and starting of the emergency power supply to restart the central operating desk.

At 12.00, product stream is led to torch, leading to large flame and release of soot (carbon black) to the atmosphere.

At the same time opening of several safety valves emitting several kinds of hydrocarbons to the atmosphere among which Benzene. Also H_2S (hydrogen sulphide) is emitted.

At 12.14, the Antwerp environmental services are by fax informed of the incident with an emergency shut down. No assistance was deemed necessary by the operator or the environmental services.

At 12.30, assistance of emergency services is requested by neighboring companies because of large soot deposits on their sites and respiratory problem of some of their personnel.

At 12.41, arrival of the emergency services at the site. They are informed of the incident.

At 13.00, the crisis staff of the ministry of the interior of the state of Belgium is informed about the incident.

At 17.15, the supply of electrical power is restarted, and preparations are started to restart the refinery.

Consequences of the accident:

In the first minutes of the incident a safety valve opened and released 70 kilograms of hydrogen sulphide (approximately 40 m^3 of pure H_2S gas).

The safety valve is situated at a height of about 40 meters. After the release a cloud of H_2S formed, which migrated, with a speed of 45 kilometers/hour in north-north-eastern direction.

Later analysis revealed that at ground level the concentration of H_2S reached about 0.6 ppm whilst in the center of the cloud the concentration was in excess of 10 ppm.

After circa 5 minutes the cloud reached inhabited areas to the north of the refinery, causing acute illness, nauseous ness, respiratory problems and a general feeling of unwell being.

In the course of the next 70 minutes the cloud traveled about 50 kilometers over Belgium and parts of The Netherlands, affecting several hundreds of people. Fifty-seven people needed medical care, but nobody was seriously injured.

The European scale of industrial accidents:

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

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

The quantity of hydrogen sulphide released to the atmosphere was evaluated at 0.070 ton. The upper classification threshold associated with this very toxic gas is set at 20 tons. Parameter Q1 is thus rated as 2 (0.07 x 100/20=0.35%).

The level 5 given to the social and human consequences is due to the 57 persons injured from the public in the Netherlands (parameter H5).

The incident had no environmental consequences and the economic consequences were not evaluated.

THE ORIGIN, CAUSES AND CIRCUMSTANCES SURROUNDING THE ACCIDENT

Origin of the power failure and following emergency shut down

Although, the plan to repair the fragile power line was tested and approved, there will remain a risk of failure, especially as in this case, half the power supply was cut under conditions of full load, thus concentrating the full load on a power line that was known to be fragile.

Origin of ventilated H2S

The safety valve that released about 70 kg of H_2S to the atmosphere opened according to plan, in order to prevent damage to the installation under conditions of an emergency shut down.

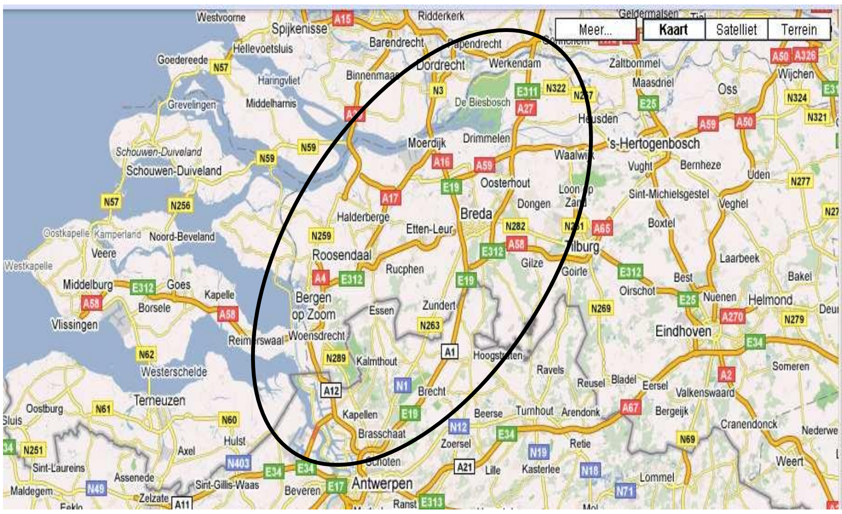
The location of the safety valve was at sufficient height, in order to ascertain that H_2S concentrations at ground level could not reach dangerous levels.

Communication

Due to the power failure, information about the status of the plant and its various parts was scarce to technicians, and in consequence during the first half hour of the incident no information was available about the nature and the amount of the emissions to the atmosphere.

As the emergency shut down was executed according to plan, no outside assistance of emergency services was deemed necessary.

As a consequence, they were not informed by the operator about the incident and the possible consequences. So during the first hour no information about the incident and the substances emitted to the atmosphere was available to local authorities or local emergency services.



It follows that also the authorities and emergency services in the affected area across the border in The Netherlands were not informed, although the Helsinki treaty obliges countries to do so. No information was made available to the public about the incident until two hours after the incident.

Several hundreds in an area up to 50 kilometers from the incident location were affected by the H_2S and experienced ill effects. Fifty-seven of them needing medical care. Nobody was severely injured, and no health effects remained after the passing of the cloud.

Due to lack of information, emergency services did no know how to react and how to treat the people who sought treatment, and no information could be given to the public until two hours after the incident.

This led to public unrest and disturbance. Confidence in authorities and emergency services was damaged.

ACTIONS TAKEN

The incident and the communication about the incident have been evaluated by the refinery's operator itself, by the Belgian authorities and by the Dutch local, regional and national authorities.

Steps have been taken to make sure that information about incidents in the area within 15 kilometers of the national borders will be given at first notice after the incident.

International notification en communication procedures between Belgium and the Netherlands will be tested in 2009.

LESSONS LEARNT

The problem was not the incident in itself, but the lack of information and communication tot the public, due to a lack of information about the release of H2S.

This led to public disturbance and unrest and damaged the public confidence in authorities and emergency services.

Notification and information, also across border, about an incident are a must.

Communication procedures, also across borders must be tested. And trained again and again.

Information about the risk of an incident have to be given to the public beforehand, in order to increase the ability to cope with an incident and its effects.

Wall rupture of a cereal storage silo and "domino effect" on a propane tank

19 August 2008

Saint-Hilaire-sur-Puiseaux (Loiret)
France

Hazardous discharge
Food processing activity
Silos
Fixed storage (tank)
Cereals / liquefied gas
Rupture
Fatigue / Ageing
Preventive inspection
Organization

THE FACILITIES INVOLVED

The site:

The company operates a cereal complex within the municipality of Saint-Hilaire-sur-Puiseaux in a hamlet named "La Bonnette" ; this complex contains:

- ✓ a silo made in 1989 of interlocking sheet pile with a capacity of 14,933 m³,
- ✓ an aboveground, 95-m³ propane tank,
- ✓ a 9-MW cereal dryer that runs on LPG.

These installations fall within the jurisdiction created by environmental protection legislation for classified facilities; the company has been granted a Prefectural authorisation to operate, dated July 7, 1989.

The closest entities to this operation are:

- ✓ another cereal complex located some fifty metres down the road in the hamlet named "La Breuille". This activity is run by the same company and falls under the classified facilities jurisdiction as well; it is composed of installations similar to those at the site of the damaged silo:
  - o a 7,150-m³ capacity silo made of interlocking sheet pile,
  - o a 70-m³ LPG tank located approximately 1.5 m from the silo,
  - o 2 cereal dryers each with a 5-MW power rating.
- ✓ a farm located about 300 m away,
- ✓ the town of Saint-Hilaire, at a distance of more than 500 m.

The involved unit:

The cereal storage silo (L = 34 m, W = 26 m and H = 28 m to the silo ridge) is composed of 6 cells each 16.5 m high:

- ✓ two square cells (8 m x 8 m), containing 1,400 m³
- ✓ four square cells (13 m x 13 m), containing 3,000 m³
- ✓ two 66-m³ bushels.

The propane tank, which lies onsite and serves to fuel the dryer, is located some 15 metres from the silo walls.

THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

The accident:

2,100 tonnes of wheat and 1,000 tonnes of corn spread over a distance of roughly 15 metres following the wall rupture on cells 3 and 5, each with a 3,000-m³ capacity, causing partial collapse of the propane tank installed in the vicinity.

This overflow of grains caused the tank to move laterally and in turn burst the LPG pipe (in gaseous phase) between the tank and the relief valve; the flow limiter positioned at the level of the tank was closed yet retained a minimum leak that was sealed off when fire-fighters closed the valve placed on the pipeline located upstream of the rupture.

The safety perimeter, established by the emergency services team upon arrival on the scene, was kept in place throughout the period of both tank unloading and gas flaring performed by the company owning the tank, at the request of the silo operator. This mission began around 6:00 pm on the day of the accident and was completed by 5:00 am the following day.

The inspection authorities for classifield facilities were informed the same day at 1:30 pm by the Interministerial Defence and Civil Protection Agency (SIDPC) of the onsite intervention of French departemental fire service (SDIS unit).

Damaged silo (source: DRIRE)

Consequences of this accident:

Only property damage was declared; no impact on the personnel, third parties or the environment was observed.


Source DRIRE


Source DRIRE


Ruptured pipe (source: DRIRE)

The European scale of industrial accidents:

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

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

Level 1 of the "Dangerous materials released" index characterises the discharge of propane, a gas listed in Appendix 1 of the *SEVESO* Directive, although the lack of detail regarding quantities emitted prevented refining this estimation any further.

The accident had no human, social or environmental consequences and thus did not require rating any of the corresponding indices.

The "economic consequences" index (parameters €16 and €15) could not be distinguished given the absence of any damage estimation.

THE ORIGIN, CAUSES AND CIRCUMSTANCES SURROUNDING THE ACCIDENT

The accident was related to the rupture of silo walls due to both the state of structural fatigue and a drop in cereal stock along with the partial tank collapse, thereby causing a gas leak. A flaw had been detected by the operator during silo construction in 1989, triggering the need for structural reinforcement works on the site in 1990.

A slight leak of cereal grains had been noticed the day before, and on the day of the accident the operator had already begun transferring grain, at a slow flow rate, from the damaged cell to an intact one. The rupture occurred one hour after this operation got underway.

The cause of this accident might have originated from the rupture of silo walls, which had not undergone any special monitoring or inspection for signs of structural ageing, under the effect of fatigue and the weight of moving cereal stocks.

According to the owner of the damaged propane tank, the gazeous leak on the tank was contained by the automatic closure of the internal limiter, and the same would have applied in the event of rupture before the valve.

ACTIONS TAKEN

The Inspection authorities for classified facilities conducted a field visit of the "La Bonnette" site and of the neighbouring silo on the "La Breuille" site the day after the accident.

The primary physical damage was recorded by inspectors accompanied by the site operator.

Besides shutting down activities on the site of the accident, a Prefectural order of emergency measures, dated August 22, instituted security measures for the damaged installations, focusing in particular on the following:

- ✓ 1 – Site closure
- ✓ 2 – Inerting the LPG tank
- ✓ 3 – Onsite monitoring
- ✓ 4 – Verification of silo structural condition
- ✓ 5 – Drainage of all silo contents
- ✓ 6 – Issuance of a burning permit
- ✓ 7 – Service start-up only after expert review.

Measures 1 through 6 above were carried out. The expert evaluations to restore the silo structure are currently underway by various engineering consultants commissioned by both the operator and insurers.

During their site visit, the Inspection authorities for classified facilities highlighted the following:

- ✓ regarding the silos: absence of any formalised approach to implementing the facility monitoring programme with a frequency adapted to the age and structural condition, as a means of preventing the risk of collapse or rupture to the cereal storage capacities, in addition to a lack of effective protection against lightning;
- ✓ concerning storage facilities for liquefied flammable gas: the sprinkling system was not hooked up to or servo-controlled by a gas detection device, absence of adequate water resources or insufficient water capacity, no safety or operational guidelines adopted, no storage logs, absence of justification for overfilling prevention.

And yet these specific points were each addressed in the Ministerial order dated December 28, 2007 for cereal storage silos that lie within the scope of application of the August 23, 2005 order as regards depots of liquefied flammable gas under this jurisdiction.

Moreover, the inspectors' report noted a perforation in the sidewall of a cell on the neighbouring "La Breuille" silo, indicating the presence of corrosion at the level of its basic structure.

As for the "La Breuille" site, the operator was addressed a formal notice to enter into compliance via Prefectural order dated September 26, 2008; moreover, the facilities inspection office requested the operator to incorporate feedback and lessons gained from the accident occurring on the "La Bonnette" site.

Beyond the specific requests submitted to the operator, the companies owning the LPG tanks on the two sites were asked to specify:

- ✓ the characteristics of tanks as well as safety equipment;
- ✓ their proposals for reducing the probability of such an event;
- ✓ their suggestions regarding LPG tank safety features, especially with respect to isolation devices (if the rupture had occurred before the valve or if the valve had been damaged, could the leak have been stopped? does the flow limiter actually suffice? would this device be the most suitable?), recognizing that valves are external devices and flow limiters do not serve the purpose of totally stopping leaks;
- ✓ the measures adopted by these companies in order to ensure that their LPG tanks are being operated in accordance with mandated safety conditions and current regulations.

On the still intact "La Breuille" site, the LPG tank was inerted; the tank will be placed back into service once it has been moved and once a new notification has been approved by the SDIS unit on dimensions of the fire water backup capacity.

The other remedial actions underway include:

- ✓ drafting of a set of safety guidelines specific to LPG storage,
- ✓ verification of all electric installations,
- ✓ a lightning study initiated with the intention of introducing, depending on the study's conclusions, a protection system,
- ✓ expert evaluation of the silo's structural condition.

A calendar of works necessary to restore all ancillary installations to the level of their contractual specifications is to be submitted to inspection authorities.

LESSONS LEARNT

No noncompliance was recorded relative to regulatory safety distances (standard order 211), even though the LPG tanks located at a distance of 15 m (on the site of the accident) and 1.5 m from cereal storage facilities lie within the silo collapse boundaries.

This accident, which was presented to national LPG and silo working groups, has revealed both the possibility of modifying the regulatory distances between various kinds of installations with special declaration requirements (such as LPG and silos) and the importance of conducting regular monitoring of installations in order to combat ageing effects*.

For silos requiring approvals authorisation (i.e. capacities over 15,000 m^3), the regulatory procedure actually requires, as part of the hazard study, incorporating and impeding "domino effects", particularly as regards safe collapse distances.

A logic diagram for structural durability audits, intended to prevent the risk of silo collapse, was also proposed at the end of 2008 by a professional farming organisation.

** Article 3.7 of Appendix 1 of the Ministerial order issued December 28, 2007 applicable to installations in existence as of August 3, 2008*

A working group was formed within a professional LPG committee on the risks and procedures for locating tanks containing liquefied flammable gas used in the agricultural sector, with the aim of proposing additional preventive measures. On this last point, one of the committee members has already indicated that all storage facilities used in the liquid phase would gradually be equipped with a manually remote-controlled mechanical shutoff device.

The commitment of LPG tank owners, within the scope of an organised entity that enables ensuring their facilities are being operated in accordance with all required safety conditions, would appear to be a highly desirable next step.

Sudden opening of a crude oil tank bottom
12 January 2007
Ambès (Gironde)
France

Sudden rupture
Wave effect
Hydrocarbon depot
Crude oil
Water and soil pollution
Facility ageing
Prevention/protection/ intervention measures

THE FACILITIES INVOLVED

The site:

The facility is a depot for oil and petroleum products: crude oil, domestic fuel oil, diesel fuel, gasoline, etc. The site comprises 28 tanks and its total capacity equalled 283,000 m³ at the time of the accident; moreover, the facility is connected to three pipeline installations and contains two wharfs. Facility operations are required to comply with a permit authorisation protocol for public utility easements ("upper-tier *SEVESO*") and are regulated by prefectural order adopted March 9, 2006.

The depot is located along the banks of the Garonne River in the vicinity of a marshland around its northern boundary, in an area containing what are known locally as "*jalles*" (pits and swampy channels).

The involved unit:

The accident occurred within the crude oil depot, at the level of tank no. 1602 (built in 1958 and containing a floating roof); on the day of the accident, the facility was storing roughly 12,000 m³ of light crude oil.

THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

The accident:

During the afternoon of January 11, 2007, a small leak was observed in the retention chamber of tank no. 1602. Since draining the tank required positioning supporting legs to hold the floating roof, the operator planned on performing this step the next day for safety reasons. In the interim, water was poured into the bottom of the tank via the bleed valve in order to limit the amount of oil leaked.

On January 12, 2007 at 8:00 am, a portion of the tank bottom broke and 12,000 m³ of crude oil spilled in a matter of a few seconds.

The earthen dykes were able to mechanically withstand the wave effect. However, 2,000 m³ of crude oil overflowed and spread on the ground and roads both in the immediate area around the depot and outside the site.

The Internal Emergency Plan was activated. The surfaces of crude oil spill at the level of the retention basins were covered with foam (170 m³ of emulsifier were used) so as to prevent ignition and contain the emanation of hydrocarbon and hydrogen sulphide vapours.

The authorities proceeded by: evacuating 12 employees from adjacent businesses, setting up a safety perimeter, closing the Garonne to nautical activities and the local road at the site periphery to vehicle traffic.

Air quality measurements were conducted by requesting site personnel as well as members of the neighbouring population to carry a passive badge monitor.

The products that spilled into the gutters and retention basin were channelled towards the site's settling pond and then transferred into empty storage tanks. Approximately 6,000 m³ of product were pumped in this manner.

Consequences of the accident:

This accident had no direct impact on human health.

The air quality measurements recorded on January 12 by emergency service personnel indicated that the lower explosivity limits had not been reached at any point in the storage facility. A hydrogen sulphide (H_2S) odour could easily be detected up to several kilometres downwind from the site and necessitated wearing masks at the depot. The crews subsequently called to repair the faulty tank needed to be equipped with self-breathing apparatuses. Since emission concentrations at the site periphery remained limited, it was possible to terminate the evacuation period for local residents after a few hours. From the outset, H_2S concentration beyond the site boundary was below the average exposure value. January 15 marked the date when H_2S content fell to zero at all measurement points.

Benzene concentrations recorded on January 12 equalled 2.4 mg/m³ at the level of the tank and 0.4 mg/m³ near the settling pond, for an average exposure value of 3.25 mg/m³. As of January 18, benzene contents had dropped below the detection threshold.

Most of the 2,000 m³ of oil spilled outside the basins was confined within site boundaries. A substantial percentage of this volume quickly reached the stormwater ditches and then by gravity flowed into the settling pond, thus triggering the immediate shutdown of pumps used for discharging pond water into the external environment, although 100 m³ did get released before pump shutdown:

- 50 m³ flowed into "*jalles*" (pits and swampy channels) located to the east of the site, where the oil polluted 2 km of ditches and infiltrated deep enough to reach the water table.
- To the west, another 50 m³ reached the Garonne River at the beginning of the flood tide period. For the most part, the oil slick remains enclosed along the river's right bank, yet it was rising at the time because of the flood-tide condition. Iridescence could be observed all the way to the *Pont d'Aquitaine* Bridge 12 km upstream. When the tide changed, the oil slick shifted downstream and reached the site of the "*bec d'Ambès*" (confluence of the Garonne and Dordogne Rivers).

To the south, the oil also spread over the ground and small roads, contaminating down to deeper layers, then crossed departmental highway no. 10, at which point it was largely contained by a parapet running parallel with the Garonne. A small quantity nonetheless seeped through and slightly contaminated the upper part of the riverbank at this location.

On January 13, traces of the spill were observed more than 20 km downstream of the depot as well as on the Dordogne River. The succession of tidal movements exacerbated the level of pollution over some 40 km of riverbanks on the Garonne, Dordogne and Gironde. The most heavily fouled 10-km stretch was found on the right banks of the Garonne and Gironde.

A few soiled birds were sighted at the time of the initial waterway inspections, yet the local ornithological protection association notified of the incident by the Prefecture did not indicate the presence of any significant impact on bird populations. The death of several coypu was also announced. In the pits ("*jalles*"), the traces found suggest that wild boars actually waded through oil dispersing drops as they continued along their path. Nonetheless, environmental groups and hunting associations did not report any exceptional impact on local wildlife.

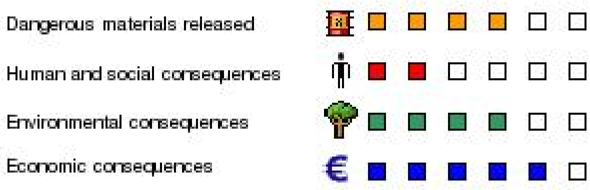
The operator proceeded with pollution cleanup measures under the supervision of CEDRE (Centre for Documentation, Research and Experimentation on accidental water pollution).

A total of 13,000 m³ of fire water containing emulsifier were stored at the depot and then underwent onsite an activated sludge type treatment by means of extended aeration.

Moreover, closure of the oil storage sector forced a crude oil extraction company to cease operations of oil wells at its Parentis Lake site (in the Landes, south-western France), whose output passes through an oil pipeline to be stored in tanks at the Ambès depot. Operations at the wells would be partially resumed a few days later, by introducing a road-based logistics organisation for transferring oil to other storage centres in the region.

The European scale of industrial accidents:

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



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

The "quantity of hazardous materials released" parameter Q1 received a 4 rating since nearly 11,000 tonnes (12,000 m³) of easily-inflammable, light crude oil were released when the tank split (22% of the upper *Seveso* threshold of 50,000 tonnes).

The "human and social consequences" parameter was rated 2 as a result of the need to evacuate neighbouring residents for over 2 hours (H7 parameter).

The parameter addressing environmental consequences was given a 4 rating given that 42 km of riverbanks and "*jalles*" were polluted and necessitated a special cleaning effort or decontamination steps (Env 14 parameter).

Economic consequences were rated 5 due to operating losses, estimated at over € 50 million (€16 parameter).

THE ORIGIN, CAUSES AND CIRCUMSTANCES SURROUNDING THE ACCIDENT

A number of critical questions were raised over both the corrosion phenomenon and the influence of the tank's unconsolidated bed on the overflow.

The most recent inspection of tank no. 1602 had been performed on February 27, 2006, while the bottom had last been inspected on April 3, 2006; the inspection method applied was a 100% scan of the bottom according to the magnetic flux loss protocol. The accident report indicated: thickness losses of between 20% and 50% over the central part, losses of 20%-80% on the periphery, and a likely 2-year life span for the tank bottom.

Seals were verified on 10% of the tank welds without any defects being detected.

Repairs were carried out and controlled following this inspection step.

ACTIONS TAKEN

Onsite measures implemented:

Subsequent to the accident, emergency prefectural orders issued January 13 and February 5, 2007 prescribed the following:

- Suspension of all crude oil tank operations
- Application of the initial emergency measures (tank drainage, crude oil pumping, etc.)
- Special monitoring of the piezometric impact
- Study of the pollution impact and planned treatment procedure
- Analysis of accident causes, evaluation of tank inspections, measures adopted to limit the probability of such an event recurring.

The foam blanket was kept in place on depot retention basins for about 2 weeks (approx. 170 m³ of emulsifier).

In order to guarantee personnel safety, the cartridge respiratory mask became mandatory gear for all site technicians during one month after operations began. A medical check-up (blood and urine tests) was performed by the occupational physician on everyone working at the depot to ensure the complete absence of adverse health effects.

Pollution cleanup efforts:

Aerial, nautical and pedestrian surveying steps were organised on a daily basis for the first five days following the accident; this monitoring served both to assess the situation (50 m³ of drifting oil spill and 40 km of fouled riverbanks) and to define intervention strategies for the Garonne, Dordogne and Gironde Rivers. The consensus priority was to stop the transfer of pollutants offsite. On January 12, major pumping operations got underway on the departmental road, in tubes and in drains. The stormwater ditches were plugged using mounds of dirt. In conjunction with this effort, oil dispersants were spread. Waterway traffic, which had been halted for a while, was reopened during the day so as to accelerate stirring of oil in the water column.


CEDRE

The "*Gascogne*" buoy tender, equipped with a weir skimmer and a tank, was mobilised although the device encountered difficulties in removing oil from the water due to strong currents and the oil spill expanse.

Absorbent strands were set into place by the coast guard at all wharfs in the affected zone in order to recover the drifting oil. These absorbent strands, along with a floating dam and later on an improvised dam, were installed in front of stormwater outlets, where salting-out tends to occur.


CEDRE

The pollution control boat, a craft capable of sailing through very shallow waters and fitted with side baskets for collecting floating waste in Mediterranean ports, began the dynamic recovery process on residual streaks of pollutants and floating waste. Its efficiency would be enhanced by lining the bottom of the lateral baskets with absorbent material.

On January 19, it was ultimately decided to build cofferdams on the banks of the Garonne using a backhoe loader at all the points where the stormwater is discharged at the level of the site. These facilities were designed to set up an accumulation pit that could be continuously monitored and pumped dry as often as necessary; they were rebuilt after every tidal movement of a strength capable of weakening the structure.


CEDRE

On January 20, a specialist company began the first-stage cleanup on the riverbanks, i.e.: collection of plates and plugs, recovery of macro-waste both fouled and clean (to avoid subsequent contamination).

The tracking and maintenance of absorbents (which serve to remove pollutant quantities rinsed by the river from its banks) at the level of the site, along with the collection of residual floating matter by the pollution control boat and first-stage containment efforts on the banks, continued until January 25.

Cleanup operations were suspended on the 25th due to snowfall and then came the weekend. Efforts resumed on January 29 and were definitively stopped on January 31 as regards physical collection efforts and on February 7 for the monitoring and maintenance of absorbents by the pollution control boat.

It was not considered beneficial to proceed with a second-stage cleanup of finer debris and pollution along the Garonne riverbanks, zones that were difficult to access, hazardous, sensitive to excessive human presence and exposed to a heavy dose of "natural cleaning" by the river. In addition, nautical surveying conducted by the CEDRE Centre on January 13 and 24 indicated that a quick rinse had been applied to the contaminated flora: the 10 km stretch least affected by the spill had already undergone a natural "cleaning" on January 24.

Findings from the March 6 survey showed that only 10 km were still polluted and moreover that the flora had started to grow back on the riverbanks. On April 5, the remaining linear stretch of pollution had been reduced to 3 km on the right bank of the Garonne. A final survey, undertaken on July 3, revealed the presence of just three small clumps of polluted vegetation in front of the depot. Since that time, no further reconnaissance operation has been carried out.

The "*jalles*" cleanup effort mobilised a total of 40 individuals for 2 weeks during the preparation phase and then another 40 for a 6-month period to oversee implementation; this operation consisted of:

- Reopening of former routes to enable access for pump trucks
- Pumping of the largest accumulations using four-wheel drive sewer cleaning trucks
- Installation and maintenance of absorbent strands and improvised dams to avoid propagation during precipitation events
- Bush clearing of all riverbanks in "*jalle*" zones to free access for cleanup teams
- Systematic soil protection using farm tarps and geotextiles for the entire set of operations
- Selective collection of floating pollutants either with skimmers or by hand
- Coarse cleaning of "*jalle*" riverbanks by means of scraping, rinsing with a fire hose and raking polluted vegetation
- While waiting for the "*jalles*" to dry, installation and replacement of absorbents in order to collect dripping pollutant at the riverbanks due to the effect of temperature rise
- Once the "*jalles*" had dried, final scraping of the riverbanks and riverbeds over a few sectors, followed by scarification for the purpose of speeding biodegradation
- Continuation of "*jalle*" monitoring activities (with replacement of absorbents and a more durable presence of improvised dams), as a step to control eventual repeat wintertime contamination, especially via the ground left untreated inside the depot area
- Tracking of water and sediment contamination throughout the 2007-2008 winter season.

Cleanup measures both onsite and offsite are still under discussion (as of June 2009), including: soil excavation, water table treatment.

Measures adopted at the regional level:

Following this accident, all operators of inflammable liquid storage facilities were requested, by administrative memorandum, to:

- Summarise the conclusions and recommendations issued by oversight bodies regarding tanks and the measures taken
- Establish an emergency procedure governing the protocol adopted in the event of leak detection on a tank
- Stipulate procedures for managing effluent in the case of a crisis (gutters, retention basins, etc.)
- Conduct an updated study on the wave effect.

Measures adopted at the national level:

A nationwide action plan with respect to verifying hydrocarbon tank bottoms was launched for 2008.

LESSONS LEARNT

Feedback from this accident has yielded three areas for further reflection and examination:

Organisation:

The accident analysis demonstrated that the introduction of tank leak control procedures would serve to better anticipate pre-crisis reactions subsequent to discovering product leaking from a tank.

Operators must obviously have access to immediate expertise and be prepared to make a quick decision regarding tank drainage in order to mitigate the consequences associated with sudden tank opening to the greatest extent possible.

Prevention:

The full analysis of accident causes, once the legal evaluation has been completed, will produce the entire set of measures capable of reducing the probability of this kind of opening.

The following points merit consideration:

- Control system efficiency
- Tank bed: better design for the next generation of tanks, improvement of existing tanks.

Protection:

This accident initiated a discussion on the need for a tertiary confinement barrier (with tank walls and retention basins serving as the first two barriers), thereby enclosing the depot and making it possible to contain eventual overflows at the site itself.

Such a regulation could incorporate:

- Limiting the probability of occurrence of spills into inflammable liquid storage zones
- Generation of a worst case scenario for the purpose of devising the appropriate technical measures to adopt.

Analyses could also be conducted in order to identify whether or not this type of accident could arise at facilities storing materials other than inflammable liquids. The environmentally hazardous products and toxic products not covered by the regulation relative to pressurised equipment have still not been addressed in the national regulation on 10-year inspections of storage tanks (Ministerial order dated November 9, 1972).

Fuel oil spill in an estuary during a transfer operation

16 March 2008

Donges (Loire Atlantique) France

Leak
Refinery
Pipe network
Fuel oil
Ageing
Corrosion
Maintenance
Pollution cleanup

THE FACILITIES INVOLVED

The site:

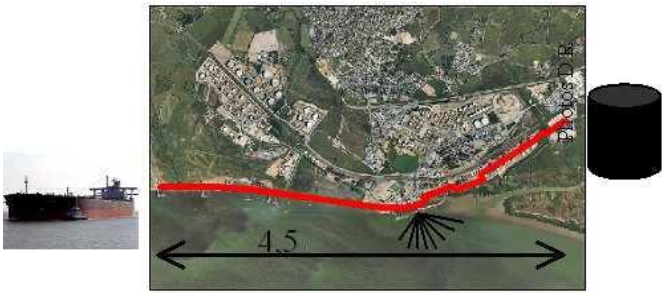
The Donges refinery, offering an annual distillation capacity of 10 millions tonnes of crude oil, is located on the northern bank of the Loire River at the river's edge in the vicinity of an expansive wetlands zone, comprising the mouth of the Loire and its adjoining marshland. This zone features a series of highly-diversified media with mudflats, reed beds and floodplain meadows being considered as exceptional here in terms of both flora and fauna.

This refinery produces, from crude oil supplied by boat, an entire array of typical petroleum products (including LPG, kerosene, gasoline, diesel, domestic fuel oil, bitumen and naphtha).

The involved unit:

The leak occurred on a pipe approximately 4.5 km long connecting a cargo fuel oil storage tank to a ship loading station.

At the leak point, the rack supporting the defective pipe runs parallel to the gas storage zone at the periphery of the Loire River banks over a length of some 300 m.



THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

The accident:

While loading an oil tanker at the refinery wharf, on a Sunday afternoon, a corroded pipe began to leak and caused 478 tonnes of cargo fuel oil to spill for 5 hours, leading to a major pollution incident on the Loire River estuary and extending to the wider coastal zone.

This leak was only detected at the very late in the afternoon and thanks to the vigilance of the crew on a barge moored at another wharf about 400 m downstream of the leak point.

The Internal Emergency Plan was activated and a crisis team assembled by the Prefecture. Significant resources were allocated to both land and aerial surveying.

Shortly thereafter, a pellets collecting ship was deployed at the mouth of the river as well as two trawlers equipped with special nets for collecting hydrocarbon pellets in the estuary. Booms were also set up in order to recover supernatant hydrocarbon.

Consequences of this accident:

Environmental impacts:

Exposed to the effect of tides and currents, the fuel oil dispersed onto the northern and southern shores of the Loire estuary. Hydrocarbon pellets were recovered on beaches in the neighbouring Vendée Department and as far south as the Isle of Rhé. Pollution cleanup efforts, in some cases requiring mobilisation of up to 750 personnel all at the same time, lasted three and a half months to clean not only some 60 km of fouled riverbanks, but also wetlands further inland (swamps, reed beds, etc.).

Public access restrictions were issued for certain beaches and fishing holes in the estuary; they would gradually be lifted between April 4 and 18, 2008.

The assessment of extent of impact on the flora and fauna was promptly initiated by conducting from the outset an accurate inventory of the detrimental effects to birds. Biweekly observations recorded by the National Office for Hunting and Wildlife revealed that that the number of bird deaths caused by this pollution spill was less than 10 throughout the entire Loire-Atlantique Department.

The proportion of soiled birds kept decreasing as pollution cleanup progressed, with the affected bird population gradually leaving the zone as time went by.

Nonetheless, several tens of dead animals were recorded in both the Vendée and Charente-Maritime Departments over the following days, even though no scientific causality correlation could be established, especially given the type of species involved.

The operator provided most of the manpower and assumed financial responsibility for all damages, pollution cleanup costs and compensation paid out to injured professionals (with a total price tag of around €50 million).

Potential health impacts:

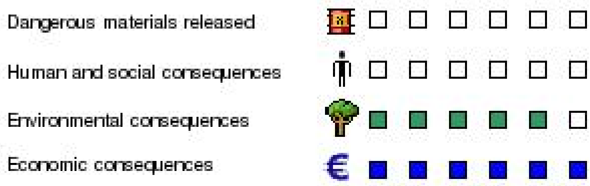
After an initial inspection conducted by a State agency on the morning of March 17, a set of health-related recommendations (i.e. how to avoid contact with the product due to its toxic nature) were broadcast via press release, transmitted to elected officials, and uploaded to the Prefecture's Website. Information bulletins on product composition, the carcinogenic potential of some of its ingredients, associated risks and precautionary measures to be respected were regularly broadcast as a follow-up step, depending on the results of analyses available regarding product characterisation as well as water and shellfish quality. Protective measures prohibiting professional and recreational ocean fishing were enacted by Prefecture order dated March 18.

Calls for prudence were posted on all beach access points, which remained open to the public, and disseminated to local town halls on March 21. Sampling campaigns on seawater and shellfish got underway on March 19 and all ensuing results were made public.

In response to complaints received by residents from the town of Paimboeuf, which was hardest hit by the spill, doctors were on call as of March 19 to identify eventual acute effects related to the pollution, yet no consultation was recorded for health problems attributable to this spill. According to the Interregional Epidemiological Cell (CIRE) with France's Public Health Surveillance Institute (InVS), short-term exposure to low concentrations of volatile compounds could be dismissed as a subsequent cancer risk for residents in the vicinity of the spill.

The European scale of industrial accidents:

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



The index relative to "environmental consequences" was given a 5 rating due to the 60 kilometres of fouled riverbanks that required intensive cleanup efforts (parameter Env14).

The costs of cleaning and decontaminating the affected media, in excess of €20 million, explain the 6 rating assigned to the "economic consequences" index (parameter €18).

The "hazardous materials released" index was not rated, since the cargo fuel oil spilled is not a material listed in Appendix I of the Seveso directive.

Due to the lack of information available on the number of third parties involved in the working restrictions issued following the accident (for industries using the ocean), the "Human and social consequences" index could not be ascribed a value either.

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

THE ORIGIN, CAUSES AND CIRCUMSTANCES SURROUNDING THE ACCIDENT

Photos D.R.

The defective pipe, 12 inches in diameter and lined with thermal insulation, was included in a group of facilities composed of some 20 pipes on two levels. An examination of the defective pipe section revealed the presence of a longitudinal crack approximately 16 cm long by 1 cm wide adjacent to observed local corrosion underneath the thermal insulator lining. Water flowing from a perforated pipe, positioned vertically with respect to the fuel oil pipeline, infiltrated under the leaky thermal insulation, first causing the steel to corrode and then perforating the pipe.

A pipe verification and maintenance programme was adopted for the refinery site in accordance with a procedure developed in April 2007 and designed to establish the various inspection and maintenance periodicities depending on the type of pipe configuration and potential vulnerabilities.

The importance of conducting maintenance specifically devoted to the pipe where the leak could be traced was however poorly evaluated in this programme, despite a number of warning signs picked up over the preceding months on this particular group of pipes and despite the potentially serious consequences that an accident could trigger for an individual pipe given its proximity to the riverbank.

The main flaws committed by the operator due to this incorrect analysis pertain to two types of actions, as follows:

Preventive and remedial maintenance of the pipes:

Several observations noted by the operator between 2004 and 2007 should have led to detecting, as part of site organisation, a potential risk with respect to the structural integrity of this heat-insulated piping:

- 7 observations of vapour leaks recorded during 2006 and 2007 on the defective rack and on an adjacent identical line, suggesting the possibility of an accelerated corrosion phenomenon at this particular site;

- The most recent visual inspection of all thermal insulation on the lines yielded, in October 2004, a total of 27 points where the insulation was found to be either out of service or deficient. This examination convinced the operator to initiate a replacement programme for a portion of the refinery's thermal insulation during years 2005 and 2006, although the replacement specific to the damaged pipe section was not scheduled until between May and September 2008. Moreover, no document on overseeing the schedule of these replacement tasks and no reasons for discontinuing the insulation replacement programme in 2006 were furnished to the classified facilities inspection authorities;
- 14 requests for service in response to a water pipe leak on the rack were received as of November 2005, without initiating a more detailed analysis regarding the potential consequences on pipes running vertically below.

Control of ship loading operations:

Ship loading operations were verified using solely the measurement of pressure present on the damaged pipe (service pressure: 12 bar). This measurement was positioned downstream of the pump that conveys product into the pipe and likewise downstream of the leak. Consequently, the small pressure variations recorded in the control room were insufficient to enable notifying the team of technicians responsible for loading operations.

ACTIONS TAKEN

Onsite:

Following both the field visits performed in the hours just after the accident and the initial set of conclusions drawn from the refinery's own internal investigation, several protective measures were implemented, namely:

- permanent monitoring from a manned station set up on the path of the pipe network running alongside the Loire;
- definitive shutdown of operations on the defective fuel oil pipe network;
- visual inspections and thickness controls at the level of special network points (braces, tapping points, etc.) after thermal insulation removal on lines over the entire rack length alongside the Loire;
- displacement of the service water pipe route in order to prevent it from aligning with any of the thermally-insulated lines of the rack running alongside the Loire.

Moreover, implementation of several technical and organisational improvement measures had been prescribed by Prefectural order, i.e.:

- Throughout the site:
- extension of the inspection schedule to both liquid hydrocarbon and chemical product lines, in incorporating their criticality with respect to environmental risks;
- formalisation of identification and treatment campaigns for degraded thermal insulation;
- formalisation of the procedure for repairing leaks on utility lines (particularly water and steam networks);
- specifications and allocation of remote detection equipment adapted to the various products and sensitive zones.
- Specific to the pipe rack responsible for the accident:
- modification of the ground lying beneath the rack, for the purpose of draining any eventual flow in the direction of a gutter connected to the refinery's oily water pipe network, thus preventing new leaks from polluting the Loire;
- installation of a detection system for all types of leaks by means of instituting permanent monitoring of all pipes located in the vicinity of the Loire; such a system is configured using thermal cameras coupled with an image management system and relay of any anomaly to the control room. This set-up is completed by a leak detection device at the level of the gutter, in case a leak were to arise beyond the field of vision of this thermal camera system;
- monitoring of product transfer operations by any means so as to ensure that quantities conveyed to the reservoir are actually received at the other end of the pipeline.

The inspection campaign carried out on all aboveground pipes positioned on the banks of the Loire entailed 120 pipe sections and consisted of more than 8,100 ultrasonic thickness measurements following thermal insulation removal on the inspected sections.

The results of this campaign revealed:

- on 5 sections, significant thickness losses due to external corrosion, necessitating repairs;

- 2 point-specific defects due to internal erosion on elbows of condensed water lines.

In addition to these defects, various tasks, including restoration of pipe lining and replacement or repositioning of pipe supporting braces, have been scheduled.

Offsite:

Monitoring of the health and environmental impacts of this pollution incident was assigned to a scientific committee composed, among others, of State agencies, specialised services, environmental protection associations and a public interest consortium responsible for sustainable development issues related to the estuary.

This committee was asked to advise Prefectural authorities in their response to the environmental impact assessment of such a pollution outbreak as well as in the resources to allocate for remedial action. This advisory body first served to inform associations of the magnitude of the incident and the initial measurements undertaken; the next step involved issuing a ruling on pollution cleanup methods so that the anticipated techniques were able to preserve the estuary's vulnerable habitat. The committee's final duty was to set forth cleanup action priorities on behalf of the bird population, in addition to a request to produce the set of specifications for a study mandated by the site operator, via an order dated July 29, 2008, relative to valuing both ecological damage and site restoration costs.

In all, 451 tonnes of fuel oil were recovered, i.e. 93% of the total pollution volume (6,200 tonnes of waste material), of which approx. 180 tonnes were spilled into the Loire.

The wastes composed of recovered fuel oil, along with the fouled flora and soils (66% in tonnage terms) and materials dirtied during cleanup, were all to undergo treatment within authorised facilities. The fuel oil and plants were incinerated, while fouled soils were biologically treated and then used at a final waste storage centre.

Communication efforts:

An information and communication system devoted to the various actors involved in this process was introduced.

This system comprised:
- a daily press debriefing from the crisis cell coordinated by the Prefect,
- creation of a cell assigned to distribute compensation to pollution victims,
- organisation of regular meetings with local elected officials and associations,
- constitution of a local information commission on estuary pollution risks (built around exchanges and information dissemination).

LESSONS LEARNT

The lessons drawn from this accident pertain to the need for a global approach not only aimed at improving prevention, but also at detecting as early as possible potential leaks so as mitigate their impact, without overlooking the organisation of intervention and remedial measures should the accident still occur despite precautions taken:

1/ Prevention measures:

- The importance of monitoring corrosion or, put more broadly, "precursors" of installation ageing in older plants and sites (which extends beyond the case of pipe networks). Special attention must be paid to:

  - ✓ "corrosion sensitive points" (corrosion beneath thermal insulation, contact with supporting braces, etc.);
  - ✓ installations positioned in the vicinity of sensitive and vulnerable zones or located in an "aggressive" environment (tidal effects, medium salinity, etc.).

- Special attention must also be paid to monitoring and maintaining pipe networks in the plant by means of establishing pertinent criticality parameters (e.g. analysis of environmental risks related to a loss of structural integrity, sampling and control modes that enable early detection of corrosion or defects, periodicity of controls adapted to degradation kinetics, acceptability criteria specific to a defect).

Following this accident and based on results of inspections carried out on the Donges site pipes, a nationwide action was launched during 2008 focusing on probe controls of pipes carrying hydrocarbons. In 2009, a widespread plan centred on the ageing of industrial installations (petroleum, chemical) was initiated by France's Sustainable Development Ministry, which by the end of 2009 will yield a national action plan.

2/ Detection and protection measures:

The efficient control of certain specific operations (ship loading, pollutant transfer, etc.), especially on expansive sites, integrates appropriate resources to be allocated to leak detection and protection as well as vulnerability of the specific media.

3/ Means of intervention:

For those media in need, an action plan is developed that prescribes tools dedicated to impact evaluation, intervention and pollution cleanup, for mandatory implementation in case of an accident; the conditions governing the availability of such tools are also to be included.

Explosions in a pharmaceutical plant

13 August 2003 and 09 August 2004

Linz

Austria

Explosion
Glyoxylic acid
Peroxide
Ozone
Design / conception
Heat insulators
Domino effect

THE FACILITIES INVOLVED

The site:

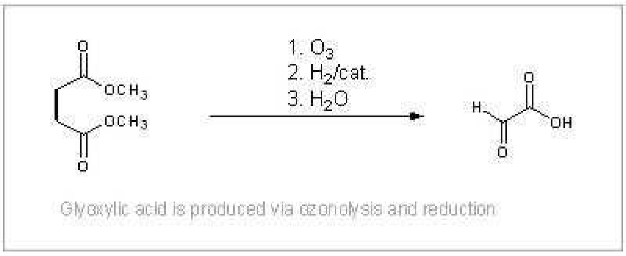
The plant is located in a chemical park in the city of Linz, where about 30 chemical companies are concentrated in order to develop synergy effects in their exploitations, such as easing the exchanges of products, energy etc.

The plant produces chemicals and intermediate products for the pharmaceutical industry ; it is classified as top tier Seveso.

The involved unit:

The unit where the accident took place includes two ozonolysis columns that produce glyoxylic acid from dimethyl maleate, methanol and ozone/oxygen in various steps.

The process involved in the accident uses ozone at –20°C and 1,7 bars. According to the operator, this process allows producing a higher quality product, thus making it a top-selling product for the company.



Source : operator's website

13/08/2003 : THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

The accident:

At 10h44, 2 columns and 2 tanks exploded in the glyoxylic acid unit during a ozonolysis reaction.

This unit contains 2 tanks and 2 columns through which the reaction mix is pumped and put in contact with an O2/O3 mixture.

The upper part of the columns are blasted, one column is ripped on 2/3rd of its height. The 2 tanks are completely destroyed and their filling (mainly methanol) caught fire. A fireball with a diameter of 80 m is formed over the installations.

Firemen from the industrial park and the city arrived on site within a few minutes. The intervention allows the fire not spread to other installations.

Consequences of the accident:

20 workers from the industrial park got injured ; they suffered from burns, bone fractures or bruises due to broken glass.

The part of the installation where the ozonolysis reaction took place (1/4 of the installation) is destroyed. Material damage are significant within a 150 m radius perimeter, mostly due to projections and broken glass. Offices are destroyed in buildings closed to the explosion.

All reactions involving ozone are stopped on the industrial park until the causes of the accident are known.

No environmental damage has been observed outside the chemical site. Most of the chemicals (mainly methanol) burned.

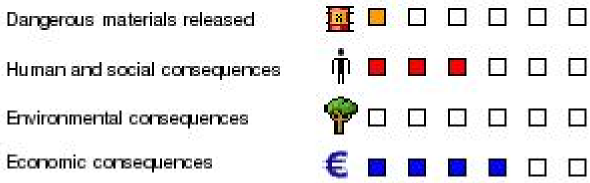
Experts from the company and from the municipality (?) are sent to the site to look for explanations on the causes of the accident.

Office at 40 m from the explosion

Workshop at 60 m from the explosion

The European scale of industrial accidents

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



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

The "dangerous materials released" parameter equals 1, the released quantity being unknown and the distance at which windows have been broken being less than 300 m.

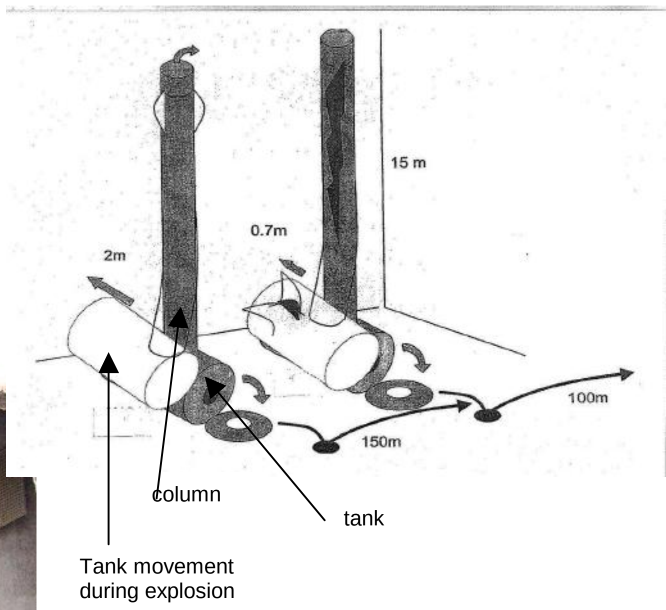
20 people got injured, among which 2 stayed over 24h in hospital: the global Human and social consequences parameter equals 3.

No environmental damages have been observed (level 0).

The economic consequences parameter reaches 4 : the company suffered one-year production losses of about 20 million euros.

THE ORIGIN, CAUSES AND CIRCUMSTANCES SURROUNDING THE ACCIDENT

The analysis concluded that a leakage (most probably leak on a flange) in a pipe released methanol / peroxide into the insulation material of the column, made of polyurethane.
Due to long-lasting high summer temperatures, the methanol (solvent) evaporated, concentrating the peroxide, which then self-ignited and decomposed.
The rise in temperature was strengthened upon contact with the rusty grid that maintained the insulation material on the column (accelerating the decomposition reaction because of metallic ions of the grid?).
The decomposition of the peroxide started the fire, which then spread and caused the explosion of the first column followed by the explosion of the second column (domino effect).



Damaged columns filled with catalyst

ACTIONS TAKEN

Following the accident, the company kept the process unchanged but installed the ozonolysis columns in a separate cold box at -20℃ in a separate building with video control. The columns are not isolated anymore, but a leakage indicator system is installed. The reactors are built to resist an explosion and a pressure relief valve is added, as well as additional safety measures such as pressure and temperature measurements.

***

09/08/2004 : THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

The accident:

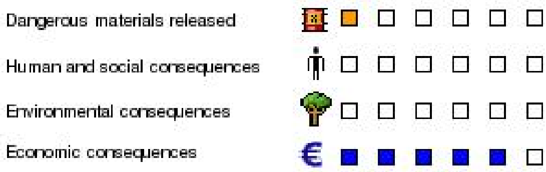
Despite the improvements in the process following the above-described accident, two explosions occurred on the same installation at 03:30 a.m. almost one year after, during the re-start of the process.

Consequences of the accident:

The explosions destroyed the devices in the cold box entirely. There was a big crack in the wall. No one got injured and no building got damaged, but a few broken glasses in the surroundings.

The European scale of industrial accidents

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



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

The "dangerous materials released" parameter equals 1, the quantity of the dangerous materials being unknown and the effects of the explosion being less than 300 m.

No one got injured : the global Human and social consequences parameter equals 0.

No environmental damage have been observed (level 0).

The economic consequences parameter reaches 5 : the company had to re-design the plant and suffered production losses of about 50 million euros.

THE ORIGIN, CAUSES AND CIRCUMSTANCES SURROUNDING THE ACCIDENT

The analysis showed that the safety concept was implemented correctly (design, planning, construction). No explosion trigger was found.

Two hypothesis of the explosions are either the creation and accumulation of foam that ignited upon local heating or hot spots (hot or catalytic particles) or the synthesis of unusual peroxides with following decomposition and ignition.

Other root causes are possible. Any future design would have to be challenged against all the possible scenarios. As a comparison, other ozonolysis users operate their systems at a lower oxygen concentration and mostly with air. Some of them use less or no flammable solvents in addition.

ACTIONS TAKEN

The company involved more than 50 experts from different countries and spend about € 400.000 for the analysis. The company modified the process to implement a reaction with air and inert gas instead of ozone.
The local government closed all ozonolysis plants with flammable dilution except for laboratories, until the causes of the accident are clarified.

The destroyed "cold box"

LESSONS LEARNT

The process was neither safe enough nor well controlled. Did the process go through a full safety analysis with identification of physico-chemical and toxicological characteristics of the substances, study of the reaction's criticity, possible secondary reactions, safe operational conditions etc. ?

One positive point is that the safety concept which was implemented after the first explosion was correct. The redesign of the reactor (cold box, leakage indicator system and advanced explosion proof reactor) allowed avoiding any injury during the 2004 explosion.

These accidents also raise the concern of chemical reactions involving (huge) quantities of flammable solvents. The risk of leakage and consequent ignition with important consequences is indeed relatively high and needs to be carefully studied. The question of domino effects should also be mentioned: were they effectively taken into account during the design of facilities?

This accident raises more generally the question of re-starting units after an accident, while root causes are not clearly identified. The re-start has been decided with additional prevention and protection means ("cold box", pressure-proof reactor and safety devices). These measures allowed avoiding any injury but were yet insufficient to prevent the second accident from occurring.

Fire within a food processing plant

30 July 2007

Renaison (Loire)

France

Fire
Pollution
Food processing industry
Fire-fighting water
Electrical defect
Retention facilities
Environmental analyses
Communication / information / crisis

THE FACILITIES INVOLVED

The site:

The pastry making facilities burned during this accident were located east of Renaison, 2 km from the centre of town and a few kilometres from the city of Roanne.

After the first plant, devoted to preparing cakes and desserts, was built in 1980, a second unit was added in 1986 for the cookies side of the operation. These two production units were combined in 1990. Then, in 1996, a Dutch group bought the site and integrated a pastry-filling shop and storage warehouse during 1998. The entire operation employed a staff of 120, running two 8-hour shifts. The plant produced pastry shells ready to be filled, including charlotte, Bavarian cream, *Genoise* sponge cake, pastries made from cream puff dough, frozen filled pastries either decorated or ready to be decorated; output was intended for food industry professionals and large and medium-sized retailers.

Administrative aspects:

The company, in accordance with regulations relative to the environmental protection of hazardous facilities, was required to comply with declaration formalities for: the liquefied gas filling/distribution plant; warehousing operations for wood, paper, cardboard and combustible materials; preparation or conservation of botanical products; and refrigeration/compression installations. This declaration requirement officially took effect on January 20, 1998.

THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

The accident:

The fire broke out on Sunday, July 30, 2007 at 2:08 am within an idle unit. Notified by the firm assigned to perform remote monitoring of the site, the Head of Maintenance sounded the alarm. Some 100 fire-fighters arrived at the scene equipped with twelve fire nozzles and three aerial ladders. They shut off the site's gas and electricity supply and had the authorities close local secondary road D9 in order to pump water from a pond located 800 m away. By 6:00 am, the blaze had been brought under control and was completely extinguished 15 hours after fire-fighters arrived. Since the fire-fighting water had been partially contained onsite, the rescue team set up a filtration barrier using bales of hay. Around fifteen emergency personnel remained at the scene the following day to check for eventual re-ignition. The mayor and the press also visited the site during the day.

Consequences of the accident:

The quantities of water used to fight the fire were extremely high, and neither the retention basin nor the pre-treatment facility were able to fully retain the 200 m³/h of fire-fighting water flowing into the drainage ditch designed for road runoff from the light industrial zone; this water then flowed into the Oudan River 800 m down-slope.

9,000 of the 10,000 m² occupied by the facility were destroyed; the loss was particularly heavy due to the considerable presence of combustibles (sugar, flour, cardboard, etc.). The refrigeration installations charged with R404a refrigerant (an azeotropic mix of fluoroethanes, whose thermal decomposition releases highly toxic and corrosive vapours: hydrogen fluoride) were damaged. The two storage silos filled with 60 m³ of sugar and flour however were completely spared. The accident resulted in no victims, but 120 staff members had to be made redundant. The entire installation would be rebuilt at a cost of € 15 million.

Debris collected in the garden of a residence 3.8 km south-southwest of the accident

Animals grazing a few kilometres south of the site were covered with soot from the fire

The captain of the fire brigade indicated to the facility inspection team on July 30, 2007 that a significant amount of black particles of varying sizes was released during the fire. The storage of cardboard and other packaging materials was found to be the source of these particles.

The day after the fire, a nearby farmer informed inspection authorities of the presence of soot, greasy to

the touch, covering vegetables in his garden; moreover, debris was strewn over his pastureland. Both the coat and mucosa of his cattle revealed an unfamiliar grey sheen.

Investigations conducted onsite corroborated this observation: blackish soot was present to varying degrees on plants in vegetable gardens and on residential decks within a corridor 3 km wide by 6 km long oriented south-southeast.

The European scale of industrial accidents:

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

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

The parameter "quantity of dangerous materials released" Q1 was rated 1 due to both the dioxin level detected in canal water following the fire and the hydrogen fluoride content released during combustion of the R404a refrigerant fluid.

The fire did not produce any human or social consequences.

The parameter tied to environmental consequences was assigned a zero rating since the watercourse did not necessitate any special cleaning or decontamination procedure; moreover, the results of analyses conducted on both the soils and crops/plants intended for human and animal consumption remained below threshold values.

The "economic consequences" parameter received a 3 rating due to the property damage sustained, estimated at some €10 million (with a €15 million reconstruction price tag).

THE ORIGIN, CAUSES AND CIRCUMSTANCES SURROUNDING THE ACCIDENT

The accident was caused by a short circuit in the electrical panels, which were installed in 1980 when the first unit was built; since then, the panels had been inspected once a year.

The fire turned into a strong blaze because it broke out in the middle of the night of Sunday to Monday; located at the periphery of a small village in a zone of low population density, the site was empty of employees at the time.

The fire scenario had been examined in the plant safety report, yet the conclusion was drawn that any fire outbreak would be quickly brought under control. Not designed to receive such large quantities of fire-fighting water, the retention facilities overflowed.

ACTIONS TAKEN

An emergency order was issued on August 2, 2007, requiring the plant operator to immediately file an accident report so as to evaluate the environmental impacts.

On the same day, the local Prefect sent a memorandum to the mayors of all nine municipalities within the sector potentially affected, notifying them that investigations (soil, water, flora) were underway and emphasising the following recommendations: for residents to carefully wash and peel all fruits and vegetables before consumption; and for the area's cattle growers not to feed their animals with fouled plants and grass.

Map of sampling operations

This fallout of soot and debris, combined with the spill of fire-fighting water, raised fears of environmental contamination from dioxin, PCB (polychlorobiphenyl), PAHs (polycyclic aromatic hydrocarbons), hydrocarbons and heavy metals. At the request of the inspection authorities for classified facilities, a sampling campaign was undertaken on August 3, 2007 within a corridor 3 km wide by 6 km long along a south-easterly direction with respect to the site; this specific zone had been established on the basis of both meteorological data and onsite observations. This study provided an initial and approximate impact assessment of the fire outside the site: on soils and plants intended for beef cattle consumption, on the liquid effluents generated by fire-fighting actions (water used for extinction), and lastly on residents' vegetable gardens to determine whether consumption was safe. The results of analyses performed on soils and crops/plants intended for human and animal consumption yielded values below the threshold; however, they also revealed areas of residual pollution due to the fire, namely on the canal used to discharge fire-fighting water.

Impact of the accident on the environment external to the site:

A canal monitoring effort was launched, along with three follow-up measurement campaigns: December 2007 for surface water and sediments; January 2008 for surface water; and March 2008 for sediments.

These water and sediment quality monitoring efforts allowed reaching the conclusion, in March 2008, that water and sediments in both the canal and the Oudan River were free of any exceptional pollution due to dioxin, PCB, hydrocarbons, PAHs and heavy metals capable of causing unacceptable risks for either the habitat or activities located in the vicinity of these watercourses. These pollutants were no longer present at more than trace quantities, which would be characteristic of background noise levels.

A comparison of analysis results upstream and downstream of the site showed that the presence of arsenic and PAH was in fact uncorrelated with the Renaison plant fire (since concentrations levels were higher upstream).

Impact of the accident at the site itself:

Investigations conducted onsite found that:

- The bare ground exhibited no exceptional levels of pollution.
- The screed laid at the former office zone (south-eastern part of the site) also exhibited no exceptional pollution.
- The covering materials (resin, tile, screed) in the former food product storage zone (north-eastern part) and debris collected presented exceptional levels of pollution with respect to organic matter, hydrocarbons and BTEX (benzene, toluene, ethyl-benzene and xylene). These coverings and debris were sent to an underground waste containment centre.

In addition, the obstructed pipes, potentially cluttered by polluted residue, were cleaned out and the waste was removed and transferred to a suitable treatment facility.

Plant reconstruction was initiated on the same exact site; 18 months after the fire, production resumed. The new installation is equipped with fire detection and sprinkling systems; furthermore, it now features adequately-sized (840 m^3) retention capabilities.

LESSONS LEARNT

In conclusion, this accident raised a number of concerns that could be manifested during many other types of events; these concerns need to be addressed, or even anticipated, at other sites:

- The effective involvement of all actors from State agencies working in the field (classified installation inspection authorities, veterinarian services, public health, sanitation, plant protection, etc.) enabled adopting an action plan that was coherent and rapid (identifying the polluting substances to target, zone of investigation).
- The heavy volume of telephone calls from affected and concerned populations proved difficult to manage for inspection authorities. A well-organised and efficient communications system that associates the various actors would help resolve this problem.
- Subsequent to the accident, the veterinarian unit with the installations inspection office of the Loire Department developed an emergency plan for issuing initial indications on how to respond in the case of a similar problem. This plan includes: a file listing the main pollutants (standards specific to component matrices, their origin, level of noxiousness in human exposure), a directory containing contact details of all participating actors and other entities (State agencies, animal rendering, the department's largest dairies, etc.), and standard correspondence and procedures explaining how to respond in case of emergency.
- Any analysis of accident scenarios must take into account, among other things: quantities of combustibles present onsite, protection and mitigation means (firewalls, smoke vents, etc.), detection devices and alarm relay protocols, internal emergency resources available and training for employees called to use such resources, and the availability and distance to the water supply.
- Retention is a key component in the set of mitigation measures available: system design must be adapted, and all devices must be regularly maintained.

Major mercury release by a battery recycling plant

21-26 January 2008

Brussels

Belgium

Mercury
Waste
Environmental impact
Gaseous discharges
Crisis management

THE FACILITIES INVOLVED

The site:

The plant, which has been classified IPPC (by Directive 2008/1/THIS, in codifying Directive 96/61/CE and its various modifications), has been set up to perform two types of industrial activities:

- cold processing: collection of lead batteries (from vehicles or industry) and their preliminary grinding in order to extract electrolyte (H_2SO_4);
- hot processing: fabrication of lead ingots out of ground batteries and miscellaneous lead waste, via transformation in a smelting furnace that produces lead bullion, for subsequent refining to yield the finished product.

The uniqueness of this site consists of exporting the pre-ground batteries output by the cold process to another plant within the same industrial group, which then performs the complete grinding operation and separation among the different components. The ground batteries are then re-imported to supply the hot processing line.

Hot processing (photo IBGE)

The involved unit:

The hot processing operation comprises:

- a horizontal rotary kiln for reducing materials that contain lead and producing a raw lead, or so-called lead bullion or first-cast lead;
- five refining tanks offering a range of capacities for the production of various alloys;
- an ingot processing line.

The fumes from both the rotary furnace and refining tanks are purified in a bag filter system prior to discharge into the atmosphere via a chimney some fifteen metres high.

THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

The accident:

The chronology of this accident has still not been elucidated, as a legal investigation is currently underway to make such a determination. The consequences and circumstances of seeking the source of pollution are described below.

The Brussels-Capital Region of Belgium is equipped with a network of stations for continuously measuring ambient air quality. The set of recorded parameters include: CO, CO_2, NO, NO_2, SO_2, O_3, Hg and fines (PM10 and PM2½).
One of these stations, located in the vicinity of the household waste incinerator serving this region, has also been equipped to measure mercury. While the mercury concentration typically measured in the Brussels-Capital Region lies within the range of 0.002-0.006 µg/m³, during the evening of January 21st and the night of the 21st to 22nd (between 8:00 pm and 1:00 am), the Hg measurement station recorded high mercury concentrations in the air, exceeding the baseline set at 0.050 µg/m³, with a Hg peak reading during the night of January 24th to 25th at 0.996 µg/m³.

Identification of the origin of this pollution required an intensive search that deployed considerable human and material resources. Moreover, contacts were initiated with Belgium's two other Regions, in an attempt to eliminate potential pollution sources located outside the Brussels-Capital Region.

As this effort was underway, Belgian authorities commissioned a scientific organisation possessing a mobile laboratory specially equipped for mercury detection and sampling. This mobile facility tracked the plume of pollution throughout the night of Friday, January 25, a step that enabled identifying the zone of highest mercury concentration.

In conjunction with this tracking operation, a certified laboratory was also engaged to conduct measurements during the same evening in the chimneys of those industries considered, according to the indicators on hand, likely sources, namely a treatment plant operating a sludge incinerator and a company producing lead ingots primarily by means of recycling the lead contained in vehicle batteries.

The corroboration obtained between information provided by the mobile laboratory and the results of measurements performed by the certified laboratory allowed, on January 29, determining with certainty that the origin of this pollution release could be traced to the hot process of the battery recycling facility. Once this finding had been announced, the identified activities were immediately suspended, and a detailed investigation was initiated in close cooperation with the legal services of the Prosecutor's Office for the Brussels jurisdiction.

Moreover, in the aim of assessing the impact of this pollution incident on both human health and the environment, the authorities also commissioned a certified consultant to carry out a soil pollution survey in the vicinity of the lead foundry. All results of this measurement campaign were addressed to the federal authority overseeing issues relative to public health so as to obtain a scientific opinion on any eventual hazards incurred by neighbouring residents subsequent to these high mercury concentrations in the atmosphere.

Even though the investigation has not yet delivered its final conclusions regarding liability, a batch of battery sets originating in France and containing mercury battery components (of the button cell variety) would apparently be the cause of this pollution release. The ensuing environmental crisis has helped build awareness that a significant quantity of mercury could be present within the lead battery recycling sector.

Consequences of the accident:

No consequences either on the health of plant personnel and local population or on the environment could be detected.

As regards the responsible company, shutting down the hot processing line for 4 months (the time necessary to develop and implement corrective measures) meant cutting working hours and proceeding with staff redundancy for a significant number of employees.

The European scale of industrial accidents:

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

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

European scale:

- Hazardous substances Q1: Since Hg is a toxic substance (R23), the *Seveso* thresholds are 50t/200t. By assuming the "worst case" conditions in considering a continuous release of 9,300 µg/m³ (value obtained during the one-time measurement inside the chimney) at 40,000 m³/h (average flow rate reported by the company) for 5 days (January 21 at 6:00 am through January 26 at 6:00 am, i.e. the period corresponding to operations of the hot processing line), the total mercury release would amount to 44.64 kg Hg, which remains below 50 kg (= 0.1% of lower tier *Seveso*).
- Human consequences: None (< thresholds associated with criteria H4 and H5).
- Environmental consequences: No remedial action necessary (< thresholds associated with criteria Env13 and Env14).
- Economic consequences: Operating losses were not quantified by the plant operator, yet they are assumed to be substantial given both the shutdown of the hot processing line for 4 months and the sizeable investments allocated to improving exhaust purification and controlling supplies and chimney emissions.

THE ORIGIN, CAUSES AND CIRCUMSTANCES SURROUNDING THE ACCIDENT

At the time of preparing this report, the legal investigation by the Brussels Prosecutor's Office was still ongoing, for the purpose of accurately determining the origin and causes of the presence of Hg in the recycled batteries, along with the circumstances surrounding the accident and all ultimately assigned liability.

ACTIONS TAKEN

Besides the fact that this incident led the company, as well as other units belonging to the same international industrial group in the battery recycling sector, to question how to ensure safety in their supply chain, a number of practical preventive measures were introduced at various stages in the industrial process in order to avoid repetition of such a discharge inside the company; these measures include:

- ensuring supplier responsibility and verification of all incoming materials by means of a manual mercury detector;
- installing an exhaust purification system featuring an activated carbon device;
- controlling purification efficiency via continuous monitoring of the rate of mercury found in the chimney;

- adopting a response and authority notification procedure in the event of exceeding any of the air discharge standard thresholds.

These measures were incorporated into a modification of the company's operating licence, which also stipulated the following:

- stricter emission standards for the other pollutants;
- higher frequency (twice a year instead of just once in the past) of emission controls by a certified laboratory;
- validation of continuous measurement devices in accordance with Standard EN14181;
- preparation of a report on the company's air pollution prevention policy, scheduled for update on an annual basis. This approach is intended to build operator awareness of the risks involved when receiving waste that had been used as raw material.

LESSONS LEARNT

This atypical pollution incident has demonstrated the need for efficiency when:

- searching for the pollution source: close coordination between the various agencies, multiple departments within the same agency and the scientific institutions called upon;
- implementing corrective measures: heightened monitoring and accompaniment of the extensive process of starting up the industrial activity;
- operating at normal industrial output: a continuous measurement system dedicated to chimney emissions, combined with adequate alarm procedures, which has in fact enabled reacting quickly and appropriately to the subsequent onset of the same kind of incidents.

The presence of many battery cells found in the crushed debris of vehicle starter batteries has underscored the importance of:

- securing the recycling operation of these starter batteries, with a line that must remain clearly distinct from the processing of small battery cells given their potential to contain undesirable substances, mercury in particular;
- possessing an efficient system for separating and sorting pieces of ground batteries in order to remove these undesirable components.

It is difficult to fully control a waste recycling operation that may contain undesirable materials, for which the filtration system installed further downstream in the process has to be chosen depending on the pollutants to be treated; it is thus essential to:

- assemble the most advanced knowledge on the various pollutants entering either normally or accidentally into an industrial process and then evaluate what might be released into the environment at the output of this process, with emphasis on conducting a regularly-updated risk analysis;
- control emissions, if possible on a continuous basis, and introduce an alarm system to ensure a rapid and effective response in case of an incident.

Chlorine cloud resulting from a failure in handling hazardous substances

5 October 2007

Frankfurt

Germany

Distributor of chemicals
Sodium hypochlorite
Mix up of connections
Generation of chlorine

THE FACILITIES INVOLVED

The site:

The accident happened at a site of a distributor of bulk chemicals such as acids, bases, aqueous solutions of detergents etc. The chemicals are delivered by road or railway tankers and put into tanks. On the demands of customs, the chemicals are then filled in drums or cans which have a volume ranging from 20 to 200 L. At the site there is also a company administration building, a building with laboratories, small scale production rooms and a storehouse. At 100 m away there is a public street.

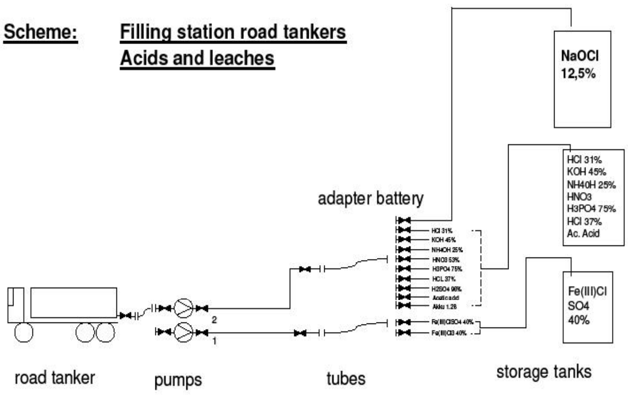
The site is neither under the regulation of the Seveso-II-directive nor the German Federal Immission Control Act (BImSchG). Thus the substances handled on the site are neither inflammable nor toxic.

The involved unit:

The involved unit consists of a storage unit with 13 tanks of 30 m³ volume, a delivery station for road tankers at a distance of about 50 m to the tanks and a filling station for drums and containers from 20 to 200 L volume. The chemicals stored in the unit are acids such as nitric acid, sulphuric acid and hydrochloric acid. Furthermore, caustic soda, FeCl(III)-solution and sodium hypochlorite solution are stored there.

The accident happened during a period of rebuilding of the unit; the filling station and the delivery station were in the process of being renewed.

At the delivery station for tankers there is a connection for FeCl3-Solution and only one connection for all the other chemicals. A pump transports the fluids via pipe to a connection battery / filling station for drums, which is near the tanks. At the battery a worker connects the pipe, by using a hose, to the right tank. Before filling, the road tanker should be weighed, delivery documents checked and a sample of the tanker withdrawn. The sample is analyzed (specific weight) in the laboratory. Then the filling is released.



THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

The accident:

In the morning of the 5th October 2007 a road tanker with 27 000 L concentrated hydrochloric acid arrived at the site. A sample of the content was withdrawn and analyzed in the laboratory. The driver connected the tanker with the delivery station; meanwhile at the adapter battery the worker of the company connected the end of the pipe by a hose with the filling pipe of a tank, unfortunately the (wrong) sodium hypochlorite tank.

When the filling was started, the content of the hypochlorite tank reacted with the hydrochloric acid and a chlorine cloud was released. The worker was aware of his failure and closed the valve. Whereby he received a serious dose of chlorine and was injured. The headquarter of the fire brigade was alerted at 10:35.

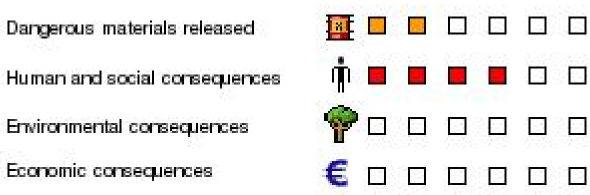
The police closed off the area and ordered the radio stations to send warnings out for the east of Frankfurt. The fire brigade saved the victims around the site and fought the chlorine cloud with water.

Consequences of the accident:

The weighing document shows, that about 1 140 kg of 31% hydrochloric acid were pumped towards the tank. About 200 kg of chlorine was released out of the ventilation system of the tank. The cloud drifted towards the administration building and the public street. Employees of the company left the building because of the chlorine smell. Other people living in the nearby public street were injured by the cloud. Besides the serious injury of the worker, 63 people (5 from the company and 58 from the neighbourhood) were taken to hospital. The worker died within 4 weeks of the accident. Within a distance of 1000 m people were asked to stay inside. A main public street was closed for a short while.

The European scale of industrial accidents:

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



200 kg of chlorine were formed, which corresponds to 0.8 % of the Seveso-threshold, column 3 (level 2).
It occurred one death and >50 injured (level 4), whereby the exact number of hospitalisation (>24h) is unknown.
No environmental damages have been observed (level 0).
The costs were less than 10.000 € (level 0).

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

THE ORIGIN, CAUSES AND CIRCUMSTANCES SURROUNDING THE ACCIDENT

The accident was caused by a human failure, a mix up of connections. Instead of connecting a hydrochloric acid containing road tanker with the right tank, the worker connected it with the hypochlorite tank. Due to the reaction scheme

$$NaOCl + HCl \rightarrow HOCl + NaCl$$
$$HOCl + HCl \rightarrow Cl_2\uparrow + H_2O$$

$$NaOCl + 2\ HCl \rightarrow Cl_2\uparrow + NaCl + H_2O$$

200 kg of chlorine were formed. (pK_a (HOCl) = + 7,5)

The following circumstances contributed to the accident :
Just at the time the accident happened, rebuilding measures were being conducted at the site. As a result of this, there was a provisional and somewhat confusional arrangement of the connections.

Secondly, the fact, that only one pipe led to the storage unit, made it impossible to use special connections for the hypochlorite.
Thirdly there was no four eyes principle established. Although the laboratory`s personnel checked the content of the delivery by analysis, the driver's action was not checked. The driver of the road tanker and the company's worker were too far away from each other, so coordinated control of their actions was impossible.

Furthermore the site is not under the regulation of the Seveso-II-directive. The requirements of the directive such as analysis of hazards, risk assessment, change control and planning for emergencies did not need to be implemented.

ACTIONS TAKEN

The operation of the storage unit, especially the filling with acids and hypochlorite solution, was shut down until appropriate measures were implemented :

1. The delivery station for roadtankers was equipped with a separate filling pipe for hypochlorite. The adapter was equipped with left hand threads.
2. All adapters of the storage unit were locked off.
3. Keys will be released after analysis by the laboratory personnel.
4. All connections were clearly labelled.
5. The hypochlorite pipe is monitored by a pH-electrode.

LESSONS LEARNT

The handling of hypochlorite solution holds a high risk. Mixing up the hypochlorite with acids will lead to a dangerous amount of chlorine. If not appropriate measures are undertaken, a simple failure will lead to great risk of life to personnel and surrounding neighbourhoods.

Other accidents with this compound in Germany forced the legislative to improve regulations. Safety regulations called rules on handling hazardous substances (TRGS 500) was renewed. Requirements on handling hypochlorite solutions as mentioned above were introduced.

Perhaps it should be kept in mind to extend the seveso directive to those chemicals ('any classification with Risk Phrase R 31: in contact with acids, liberates toxic gas'), if the directive is reworked.

Transboundary pollution accident
River Daugava (Latvia)
23 March 2007
Latvia

Hazardous release
Transboundary pollution
Surface water pollution
Pipeline
Diesel fuel (hydrocarbons)
Ageing
Organization
Response (difficulties of)
Crisis communication

THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

The accident:

On 23rd March 2007, Latvia received some information about leakage from the oil product pipeline "Unecha-Venstpils" in Belarus about 130 kilometres from the border of Latvia.

Belarus officially informed Latvia of the spill on the River Ulla on 24th March - 17 hours after the spill occurred and the slick began its drift toward the downstream River Daugava.

Leakage occurred in the Vitebsk area (northern Belarus) close to the River Ulla – Belarusian tributary stream of River Daugava – the biggest river of Latvia. The Daugava is Latvia's largest river and before reaching the Gulf of Riga - an offshoot of the Baltic Sea flows through both Riga and the country's second city, Daugavpils.

The rupture of a 377-millimeters oil pipeline for 5 hours resulted in approximately 120 tonnes of diesel fuel spilled into River Ulla and then into River Daugava.

Pipeline owner had no immediate comment on the spill.


Latvian Coast Guard Service


Latvian Coast Guard Service

Consequences of the accident:

Pollution from this source affected 2 countries – Latvia and Belarus. Leakage of approximately 120 tonnes of diesel fuel also contaminated 1.2 hectares of land at the source. The oil slick extended over 100 kilometres downstream, around 30 per cent of the river's width has been affected by the spill. The clean-up operation prevented much significant long-term damage from the spill.

The oil company responsible for the accident paid 170 000 EUR for the costs of emergency activities and direct damage to the environment. At the same time some environmental scientists estimated that the overall costs of this accident in Latvia, including environmental damage, indirect consequences to the environment and clean-up operation at approximately 440 000 €.

During the clean-up operation international assistance was received - Estonia had dispatched six volunteer workers and Sweden had sent booms, which were deployed across the River Daugava.

Direct consequences on fauna and flora were estimated by State Environmental Service, involving scientists from the University of Latvia. Such parameters as oil content in water/sediments, toxicity of water, ecotoxicity of river fauna/flora, oxygen demand were measured, biological tests incorporated species that are considered sensitive and representative and included tests on acute toxicity, chronic toxicity, potential of bioaccumulation and potential for bioaccumulation. As a result, direct damage to the environment was calculated by assessing the scale of affected river fauna and flora. The results of Latvian University's research concluded on non-significant lasting impact caused by the pollution on the environment. Moreover, the evaluation of influence of pollution on fish natural feed reserves (analysis of biomass, variety of species and number of species – zooplankton and benthos) didn't show significant damage, possibly due to the early spring season.

The European scale of industrial accidents:

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

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

The dangerous material released Q1 parameter was rated at 2 due to the release of 120 tonnes of diesel fuel (0,48 % of the 25 000 tonnes upper threshold of the Seveso II Directive).

No human or social consequences have been found.

Environmental consequences were rated at level 5 on account of the 100 km of river polluted (Env 14 parameter).

Level 2 rating was given to the "economic consequences" index as the official costs of damage to the environment and emergency activities were estimated at 170 000 € (€18 parameter).

THE ORIGIN, CAUSES AND CIRCUMSTANCES SURROUNDING THE ACCIDENT

Latvia and Belarus are linked by Soviet-era pipelines built to carry Russian oil to the ports of the Baltic. However, much of the infrastructure is outworn and needs to be renovated. Also in this case - ageing was the reason of the accident.

Due to the spring season, there was strong stream and very high water level, as well as unstable ground of riverbank, which made impossible deployment of booms directly on the border of Latvia and Belarus to prevent transboundary pollution.

ACTIONS TAKEN

Belarusian environmental services had gathered and utilised 90% of the leaked fuel at the source. Approximately 4 tonnes reached Latvian territory.

Initial attempts by Latvian rescue services to place preventive booms across the river at the border of Latvia and Belarus were hampered by high water levels and rapid currents.

The second attempt of deployment of booms 50 kilometres downstream was successful. In total more than 4 tonnes of oil products pollution was collected. The size of the spill was constantly fluctuating and the main concern was that the leakage would continue longer than we predicted initially.

Observation of 40 sites in affected area was made during clean-up operation and during monitoring of affected area later on.


Latvian Coast Guard Service


Latvian Coast Guard Service

The management of emergency situation included co-ordination of several institution: State Environmental Service, State Fire and Rescue Service, Latvian Coast Guard Service and Ministry of Foreign Affairs (international Operations and Crisis Management Division) as well as nearby municipalities.

Latvia filed an official claim with Belarus to ask for compensation for its losses incurred by the spill and for the clear-up efforts to collect the pollution.

Latvian emergency services had to work for about a week to collect the oil slick and to stop it from reaching the capital Riga.

During the clean-up operation instant operational communication was held between the state services - Latvian Coast Guard Service, State Fire fighting Service, State Environmental Service etc.

Co-ordination of emergency operations was established already at the beginning by convening the Government Crisis Management Council. Also international communication with Belarus was established through the Ministry of Foreign Affairs. Requests for assistance were dispatched to the neighbouring countries - Sweden, Estonia and Lithuania and emergency equipment was received, such as absorbent and river boom, as well as rescue brigades from Lithuania and Estonia.


Latvian Coast Guard Service


Latvian Coast Guard Service

A lot of effort was put into public information and media. Information was given to the public on:

- Prevention of possible use of polluted water;
- Current information on environmental condition of affected area;
- Regular summary about activities of Environmental and Rescue services.

No official restrictions on water use were announced due to the monitoring results of pollution levels in the river, which did not exceed the permissible levels.

As a result of clean-up operation the main waste consisted of used absorbent booms, which were collected and delivered for destruction to the waste incineration plant in Latvia.

The following follow up activities were carried out:

- Cooperation with University of Latvia to assess damage to the environment on the territory of Latvia;
- Regular monitoring of affected area (sampling, laboratory analysis, visual);
- Submitting of invoice to oil company - total costs of estimated damage to the environment and costs of emergency activities (~170 000 EUR).

LESSONS LEARNT

The organization of the emergency and rescue operations required rapid assessing the extent of pollution and its actual and potential effects. The sufficient level of information exchange is very significant in case of transboundary pollution accident.

The clean up methods (deployment of booms) as well as assessment methods of damage of the environment (Bonn Agreement Oil Appearance Code: BAOAC) was successfully used in this case.

During consultations between the Ministries of Foreign Affairs of Latvia and Belarus in Minsk (Belarus) it was emphasized that there is a need of expanding the legal framework in order to prevent and successfully resolve similar situations in the future and a need of signing the technical protocol On Exchange of Information between the Ministry of Environment of the Republic of Latvia and Ministry of Natural Resources and Environmental Protection in Ecological Crisis Situations of Belarus, and the multilateral agreement On Use and Protection of Water Resources in the Basin of Zapadnaya Dvina/Daugava.

Pollution of the port of Sillamäe by hydrocarbons produced from oil shale

12 September 2008

Sillamäe

Estonia

Hazardous release
Water pollution
Hydrocarbons
Phenol
Hydrocarbon depot
Rainwater network
Sump
Maintenance
Organization
Alarm

THE FACILITIES INVOLVED

The site:

The involved unit:

The oil terminal company is specialised in storing and loading of tankers with different oil products.

Products arrive by rail and are stored in 12 reservoirs with total capacity of 172 500 m^3. The reservoirs are in 3 reinforced concrete embankment areas. To protect surface water, the area is covered with a geomembrane, which is covered with a layer of sand and a layer of crushed stone. The edges of the geomembrane are turned up to the embankment and the basements of the reservoirs.

Rainwater is collected with drainage tubes in the crushed stone layer and directed through oil catcher to the sea. Drainage of each embankment area is equipped with valve that is usually in “shut” position. The accumulated water is discharged by opening the valves. Each embankment area can hold 110 % of the capacity of the biggest reservoir. In the cases of leakages of reservoirs or pipelines, the geomembrane will keep the product in the embankment area. The oil is collected in the drainage wells and pumped out. The contaminated sand and crushed stone will be replaced.

The turnover of oil products in the terminal together in July, August and September 2008 was as follows:

- Shale oil 22 944 tons;
- Fuel oil 111 971 tons;
- Vacuum gas oil 112 837 tons;
- Low sulphur fuel oil 1 851 tons.

Shale oil is Estonian specific fuel produced from local mineral - oil shale. It is hazardous for the environment, including risk sentences R51, poisonous for water organisms and R53 and can have a longer term harmful effects in waters.

THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

The accident:

On the 12th of September 2008 Port of Sillamäe reported Environmental Inspectorate on a pollution of sea on its territory. Inspectors found out that the pollution was discharged into the sea from one of the outlets of the heating station. At first there was no information from where the oil had reached the outlet. Due to the wind from the direction of the sea the pollution had not spread to the open sea but stayed near the coastline. The length of the coastline beside the dark pollution that could be noticed in the sea was about 150 m. The localization of oil in the sea was organised by the port and terminal authorities using special boom.

Typical smell of shale oil was in the air. Inspectors took samples from the sea, the outlet and made photos. Moving upstream the open sewage channel, the inlet of polluted water from the drainage system of the oil terminal was found. Sample of polluting material was taken from this place.

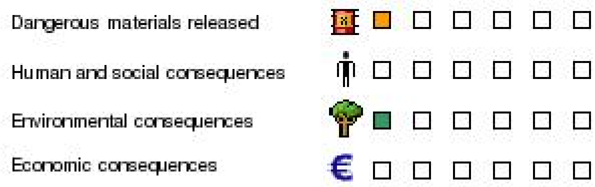
Consequences of the accident:

As the Port of Sillamäe found oil in the harbour territory, it informed Environmental Inspectorate and the municipal administration. According to the pollution response plan the port is responsible to take action in combating the pollution. The possible spreading of oil along the coastline was constrained by special boom that is part of the obligatory equipment of the port. The oil was collected with shovels during the next days and stored in 200 litre barrels. The collected material was given to a special hazardous waste treatment facility. The contaminated booms were also given for cleaning to the same company. After separation of the 2400 kg of collected mixture of oil and seawater it was measured that the amount of polluting substances was 240 kg. Three samples, taken from the polluted site gave the content of 1-based phenols as 0,0558 mg/kg, 0,0486 mg/kg and 0,0421 mg/kg. So it can be assumed, that the 240 kg of pollution contained about 12 mg of phenols.

Phenols are soluble in water and their amount released to the sea was not identified in this case. The Estonian maximal admissible concentration of phenols in seawater is 0,001 mg/l. 1-based phenols are Estonian specific priority hazardous substance that is monitored and reported.

The European scale of industrial accidents:

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



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

The dangerous material released Q1 parameter was rated at 1 due to the release of 240 kg of hydrocarbons containing 1-based phenol at an average concentration of 0,05 mg/kg (<0,1 % of the 200 t upper threshold of the Seveso II Directive).

No human or social consequence has been noticed.

The environmental consequences parameter was rated at 1 on account of the 150 m of coastline polluted (Env 14 parameter).

The economic consequences of the accident are not known by the public authorities as companies are not obliged to report the costs they have carried in combating of pollution themselves.

THE ORIGIN, CAUSES AND CIRCUMSTANCES SURROUNDING THE ACCIDENT

The emergency plan of the oil terminal considers the burning of the big reservoirs as maximum accident. The 2nd most important aspect of the accidental cases is the movement of polluting substances through the surrounding ditches towards the sea. The oil products can be emitted to the aquatic environment in the cases of breakage of equipment, overfilling of the reservoirs or accidents with railway tank wagons. The accidental emissions of oil products could be long-lasting through a small hole or thrown immediately in great tears.

The emission of oil products into the soil and surface water was considered to be excluded during the normal operation of the terminal. The reaching of great amount of oil products to the sea was considered not much likely as in this case all the valves near the reservoirs and in the pumping station should be in open position at the same time.

As the inspection on September 12th showed there had been recently a leakage of vacuum gas oil during the loading from the railway tank wagons. The railway is built on a reinforced concrete pool that is filled with crushed stone and the rainwater is discharged through a drainage system equipped with oil separators. The pumped rainwater is discharged into the sewage system of the nearby heating station and should reach the Baltic Sea. The system has valves and a well, which collects the oil products that have leaked. These should be pumped out from the well.

Actually for a long period the leaked oil products had not been pumped out from the pool under the railway. Thus, not only the recently leaked vacuum gas oil, but also significant amount of previously loaded shale oil reached the ditch running towards the sea.

The discharge of pollutants from that ditch into the sea is regulated by environmental permit. The holder of the permit has the task to measure periodically the content of polluting substances and the amount of the water discharged into the sea and to calculate the pollution load. According to the amounts of discharged substances, environmental charge has to be paid to the state budget.

The limit concentration for oil in the water in the discharge point was 1 mg/l. The measured content of oil was 0,032 mg/l and the amount of discharged water in July, August and September was 500 000 m³. Thus the regular amount was calculated 0,016 tons of oil discharged during three months. Phenols were not regulated by the permit and there was no obligation to monitor them.

The sample of water taken on September 12th showed a concentration of 340 mg/l of oil and 0,0558 mg/l for 1-based phenols. That was the main basis of evidence of the violation of the water act. The other evidence material was the identification of the polluting material of different samples including also the sample taken from the oil separator of the loading station on the railway.

According to its emergency plan, the oil depot had to observe the situation of the well and the valves constantly but it was not fixed more precisely how to keep records on that procedure. On that inspection day there was no more evidence why did the oil overflow suddenly from the well and if there had been smaller releases into the sewage system earlier.

ACTIONS TAKEN

The following shows how environmental legislation was used in practice. It was complicated for the environmental administration, as the accidental discharge of polluting substances occurred in the wastewater discharge system that belonged to another company, which had applied for permit to discharge wastewater and substances in this water. This company was not a public water supply and canalisation company. This holder of the environmental discharge permit was thus made responsible to control its clients himself.

- on September 12th Environmental Inspectorate composed a protocol in order to inspect the polluted site that included also the inspection of the site that caused the pollution of the sea.
- on September 15th analytical comparison of oil samples was ordered in Central Environmental Research Laboratory.
- on September 17th the waste handling company was requested to measure and inform the administration about the amount of collected oil.
- on October 2nd administrative violation protocol was composed to the holder of the permit to discharge wastewater. The holder of the permit had no right to discharge phenols and the maximum permissible concentration for oil products was significantly less than it was measured the sample taken on the 12th of September.
- on October 24th the Regional Environmental Department, who approve the wastewater discharge calculations and collect the pollution charges, made a correction to the calculation of permit holder. The company had calculated usual pollution charge, which took into account “the overall compliance coefficient 0,5”. Thus the permit holder had to pay 26 720 € for pollutants in discharge outlets, instead of originally calculated 13 360 €.
- on October 30th the decision of administrative penalty in amount of 1 000 € together with the obligation to compensate the proceeding costs in amount of 3 000 € was put on the owner of the permit.

The depot owner company has planned to equip the drainage water collection and discharge system with an alarm signalisation. The permitting authority can decide on revoking the environmental permit if the company having the permit is not aware of the situation of its clients.

LESSONS LEARNT

This incident led to the following lessons learnt:

1. to prevent environmental pollution, legislation should foresee higher rates of environmental charges for illegal emissions, and the administration should be able to apply them. In this case the application of higher charges served as a tool for sewage discharging company to control its connected clients;
2. lessons from accidents lead the control authorities to the matters which should be paid more attention during permitting and inspecting;
3. preparedness to combat oil pollution should be in place;
4. the shut valves, that can be opened only in special cases, should be equipped with alarm and signalisation to avoid negligence;
5. the oil separators and the collecting well should give signal to the operator if it is full or needs cleaning.

Flooding of a pharmaceutical plant

1st November 2008

Saint-Germain-Laprade (Haute-Loire)

France

Natural risks / Flooding
Intervention / rescue / Internal Emergency plan
Securing
Water damage
Operating losses
Batch process
Restart

THE FACILITIES INVOLVED

The site:

The site manufactures pharmaceutical active ingredients and is subject to permit with an easement under the legislation of classified facilities to manufacture and store chemicals that are toxic, hazardous to the environment, inflammable and violently react to water.

The plant located in the St-Germain Laprade industrial zone sprawls over 55 hectares including 15 hectares of construction.

St Germain Laprade industrial zone (source: L'Eveil de la Haute Loire)

THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

The flooding:

Following a spell of torrential rains (about 300 mm from 31 October to 2 November with a 3-hour extremely heavy downpour), insufficient draining of the water from the catchment area housing the industrial zone caused flooding. The water level in the entire site reached 20 cm to 1 metre.

Since manufacturing was underway, the staff sounded the alert even before rise in water level in the plant.

The operator triggered the internal emergency plan (POI) on Sunday 2 November around 4.00 am and set up a crisis management division comprising 6 units (intervention, communication, engineering, information, operation and logistics). The operator deployed significant resources to raise or evacuate the equipment and material, keep the most important (from a safety and financial standpoint) chemicals away from water, stop manufacturing processes along with a safety fold back of equipment (safety stand-by phases identified in the safety cases of chemical reactions except for a reactor being heated which had to be cooled before shut down) and plan out power cuts before the water could flood sensitive equipment.

In the event of an emergency, each reactor could be safely folded back by pressing on the automatic shut down button. This solution was not used as a shut down option to avoid any impact on the quality of products in the reactor and enable an easier start. Only 5 out of the 12 inverters could be shut down before the rise in water level. The 7 others had to be replaced but had no negative impact at the time of the incident.

The group operating the Saint Germain Laprade site had seen two other cases of equipment fold back on account of flooding of a pharmaceutical active ingredients manufacturing unit: at Saint Germain Laprade in 2003 for less than 24 hours and in the USA.

The staff present onsite included:

- Before the incident: 12 people
- After triggering the internal emergency plan: 30 people
- Sunday 2 November: 50 people from the plant + 10 people from outside companies
- Night of 2 to 3 November (from 11.00 pm to 6.00 am): 7 people from the site
- Monday 3 November: 150 people from the plant + 55 people from outside companies
- Then 200 to 220 people including over 30 electricians and equipment technicians

Since the leak detectors especially gas indicators were not functional due to the power failure, the staff patrolled the site performing manual measurements of gases, listening to strange noises and watching out for any possible incidence of heating or leaks.

Additional resources were called in: a truck and a power lift truck capable of working in wet environments to move objects. Two high-speed pumps (850 m³/h) provided by the national civil safety department of the French Home ministry were used to rapidly drain the residual water on Monday 3 November. At around 1.00 pm, the water was drained from the site.

Production facilities, air cooling towers as well as electrical equipment and rotating machines were re-commissioned with precaution and monitored.

Consequences of the accident:

The chemical plant was completely flooded where the water level was between 0.2 et 1 m. Damage within the plant was relatively limited thanks to the prompt action taken by the operator. The flooding however resulted in significant water damage on some equipment or in certain premises (Perimetrical system for the detection of intrusions, changing rooms, laboratory partitions, low-lying equipment, etc.). The operating losses were limited despite the shut down of the plant for several days.

The products stored in refrigerated containers were not impacted despite the lack of power supply to the refrigeration and presented no risk of instability in the event of rise in temperature. Except for 200 g of a laboratory chemical in powder form and 2 to 5 litres of a hydrocarbon compound, no significant amounts of environmentally hazardous product were lost. The basins of the liquid effluents treatment station were not flooded.

Some wet administrative documents (manufacturing files, product quality certificates for instance) were packed in water tight bags to be recovered using cryogenic treatment.

Preparation of wet documents in plastic bags for cryogenic treatment

The 4 thermal motor-driven pumps for fire protection including the starter batteries were not affected by water due to the high-level storage condition laid down by the insurer. However, automatic start up was not possible due to the power cut.

No incidents of pollution were observed. The loss of identified hazardous material or pollutants was rather low: 5 l of hydrocarbons and 200 g of chemical powder in the laboratory.

Changing rooms during flood

Changing rooms after flood

The European scale of industrial accidents:

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

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

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

Since the flood did not result in any casualties, or environmental damage, the overall level of the "dangerous materials released", "Human and social consequences" and "environmental consequences" remained 0.

The flood resulted in relatively limited damage to the plant and low operating losses thanks to effective organisation and prompt re-commissioning of facilities. The losses were estimated at least 10 m euros in the beginning of 2009, rating the "economic consequences" index at 3.

Drying and dehumidification of premises after cleaning and disinfection

THE ORIGIN, CAUSES AND CIRCUMSTANCES SURROUNDING THE FLOODING

The torrential rains during the previous days resulted in the flooding of the site. The St Germain Laprade zone was not located in easily flooded zone but since the site was located in a natural depression, it was flooded even though the platform was raised from 0.8 m to 1.5 m at the time of construction of the site.

The flood occurred due to insufficient draining of the water from the catchment area housing the industrial zone given the torrential downpour over a short span.

Less intense showers were (no buildings effected) experienced in 2003. The water level reached was 662.2 meters (site platform stood at 662.5 meters). The water reached a level of 663 metres in 2008.

ACTIONS TAKEN

During the fold back of facilities, checks were made to ensure the phase of fold back was in line with the predicted status. The status of each production unit was printed from the control station before cutting off the power supply. The operator had planned to gradually re-commission production facilities with a stronger technical back up team. The equipment was isolated in safety position before the automats were re-started even though the risk of a faulty order was not present as the automats were shut down normally.

The air cooling towers were re-commissioned after the chlorine treatment upon start up in single loop followed by another chlorine treatment upon re-commissioning of their network. Samples were taken to screen for legionella.

The thermal oxidiser for volatile organic compounds was stopped properly. However, it was precisely monitored upon re-commissioning: monitoring vibrations, checks with infrared camera, etc.

Since the electrical equipment and rotating machines were in contact with water, they were scheduled for inspection and treatment by a specialised staff and were more closely monitored for several months.

The risks on account of moisture on equipment that was not directly in contact with water can be ruled out given the presence of water in the premises and the low hygrometer reading.

The effected insulators were taken apart and checked using infrared camera.

Following this incident, the DRIRE (Regional Directorate for Industry, Research and the Environment) ordered a special study on the risk of subsidence, especially the subsidence of land and equipment and requested a follow-up.

The safety studies completed in July 2003 had indicated the risk of rain water stagnation in the site. After the flooding in 2003, the operator has improved the site's water drainage system but no initiative has been taken on public infrastructures.

Even though the prefectoral order dated 25 November 2004 authorised the site's operation, the scenario of "flooding" was not included in the internal emergency plane (POI). As part of the revision of the site's POI, it was planned to take flooding into account However, even though flooding was not provided for in the POI, its technical and organisational modalities were applied by the operator to guarantee the safety of the site and reduce economic losses.

The metropolitan authorities launched a local hydrography study at the end of 2008 for its results to be published in 2009.

A part of the public pits were improved after the floods.

NB: the order dated 24 December 2008 (published in the official gazette JO on 31/12/2008) officially declared the town of Saint-Germain-Laprade to have been struck by a natural disaster on account of the flooding incident from 1 to 3 November 2008.

LESSONS LEARNT

The main lessons learnt from this event as of date include:

- Flooding can occur even in a zone that is not classified as an easily flooded zone.
- Flooding does not necessarily occur due to the increase in the water level: the risk of flooding of an industrial site must be evaluated by taking into account the entire catchment area. This evaluation must also be regularly reviewed to take into account the changes (waterproofing the surface, development of infrastructures, modification of water flow systems, etc.).
- An early alert is crucial to put together the crisis management unit and organise all rescue operations.
- The setting up, organisation and the appropriate sizing of the crisis management unit is of prime importance: a system or a tool to contact the key players of the unit must be available to gather the necessary resources (take into account all updated telephone number).
- Cutting off power supply to electrical equipment before any contact with water is recommended.
- It is important to know the safety fold back stages of the facilities for a safe shut down. Safety facilities are a must as flooding of power or IT lines result in a loss of monitoring and control systems.
- Infrastructures preventing any contact with water (dams or storage at an altitude higher than in all flooding scenarios) must be included in designing areas designated to store chemicals that violently react with water.
- Sensitive products (hazardous products and materials, etc.) and if possible mobile sensitive equipment and important documents must be stored above the maximum predictable water level.
- Raised inverters must be installed as far as possible to avoid any fault in the batteries as even if the batteries can be isolated, thy cannot be “drained” of the accumulated charge.
- It is important to have a detailed list of resources need in the event of flooding, and sufficient equipment for the initial operations and reconnaissance (elevation devices, sealing and absorbing products, boots and hip waders, etc.), as well as a list of companies specialising in cleaning, drying and disinfecting operations. These companies can be contacted at the start of the incident to ensure a return to “normality” as fast as possible.
- Wet documents can be conserved through proper treatment (storage in air tight bags and special cryogenic treatment).
- The onsite presence of equipment enabling intervention in flooded zones such as large-wheeled power lift trucks with exhaust pipes and air vents at higher levels, as well as powerful pumping devices is extremely useful in securing sites and draining the flood water. Especially safety equipment such as fire pumps and their accessories such as starter batteries and their fuel tanks must well above ground level.
- During floods, patrolling must be carried out with a view to minimise accidents or incidents of pollution by taking readings with gas indicators, looking out for strange noises, heating and leaks.
- Electrical equipment can be re-commissioned only once they are dried (in case of equipment not having been in contact with water and consequently showing a low hygrometer reading, it seems useful to monitor the hygrometry especially during hot season or in a hot zone).
- Insulators submerged in water or wet due to capillarity must be taken apart for examination and replaced if needed. In addition, they must be monitored after re-start using an infrared camera, etc.
- The chances of a faulty order upon re-start of facilities (especially automats) must be examined. Safety fold back may be planned to counter such a risk.

- Production restart mode must be precisely defined: identification of the dangerous characteristics of reaction media, analysis of risk of clog or deposit formation or product accumulation in manifolds and pipes leading to a risk of mixing of incompatible substances, a re-verification procedure similar to one initiated subsequent to a significant modification, reinforced technical supervision, etc.

- Electrical equipment and rotating machines must be even more closely monitored by qualified staff for several months after the incident.

- Air cooling towers require special procedures before restart (emptying after shutdown over long periods and high temperatures or water in the circuit, disinfection, screening for legionellla upon start up, etc.)

- After draining the flood waters and drying the ground, an analysis of the risk of subsidence, especially differential subsidence may be required to prepare follow-up.

Lastly, with the climate changes, exceptionally intense rains can be expected in the forthcoming years. Will the current standards based on 50 mm of rainfall over 2h suffice in calculating the run-off?

Quick overhaul of facilities (drainage of water, cleaning, drying, tidying up)

Ammonia water leak
20 December 2007
Laneuveville-devant-Nancy (Meurthe et Moselle) France

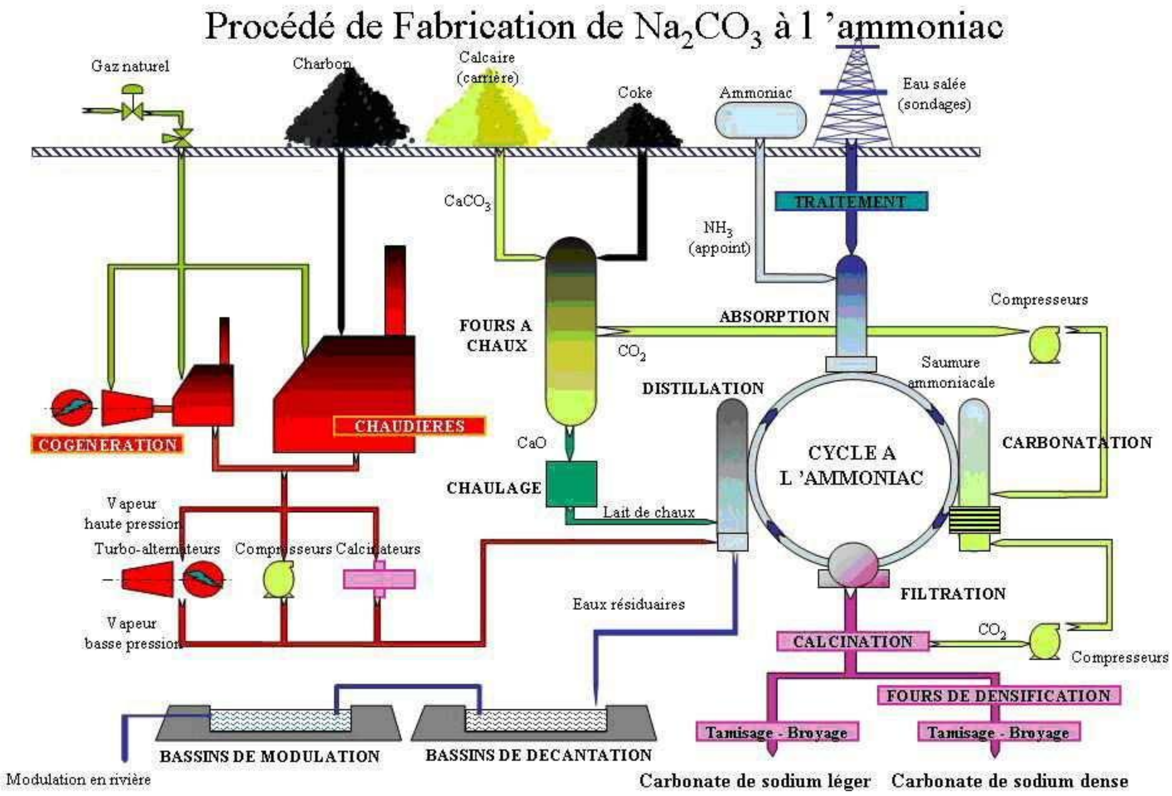
Ammonia
Atmospheric pollution
Material failure / pump
Clogging
Maintenance / Work
Organization / Detection
Communication / Crisis

THE FACILITIES INVOLVED

The site:

The factory operates a soda ash plant with some 400 employees; the company had been granted the authorisation to produce 600,000 tonnes/year of sodium carbonate, or soda ash, for use primarily in glassmaking, the chemical industry and for manufacturing detergents. This facility has been operating since the end of the 19th century in Laneuveville-devant-Nancy (French department 54) south-east of the city of Nancy in what is the Lorraine region's salt basin, as evidenced by the presence of salt mines, which supply one of the plant's raw materials, i.e. brine and limestone.

The salt (sodium chloride) and limestone (calcium carbonate) ultimately transform into sodium carbonate and calcium chloride as an effluent solution discharged into settling basins then channelled into the Meurthe River, depending on the river's level of hydraulicity, via a transition basin. The chemical reaction that yields sodium carbonate is catalysed by the ammonia according to the following formula: **$CaCO_3 + 2\ NaCl \rightarrow Na_2CO_3 + CaCl_2$**



The soda ash plant is subject to legislation on classified facilities, specifically regarding the following operations:

- production of sodium carbonate, under the terms in heading 1631 of the classified facilities nomenclature (absorption columns, carbonation columns, distillation columns, etc.);
- ammonia storage, under the terms in heading 1136 of the classified facilities nomenclature for a quantity in excess of the lower *SEVESO* threshold for hazardous facilities, as defined in the May 10, 2000 order (two ammonia tanks 45 tonnes each, for a total of 90 tonnes);
- lime manufacturing, under the terms in heading 2520 of the classified facilities nomenclature (lime kilns with a total capacity of 1,400 tonnes/day);
- combustion and cooling, under the terms in headings 2910 and 2921 of the classified facilities nomenclature (calcining and densification furnaces, a major combustion installation at 220 MW, with a "TAR" rating of 200 MW);
- handling of salt discharge, under the terms in heading 167C of the classified facilities nomenclature (three settling basins and one transition basin).

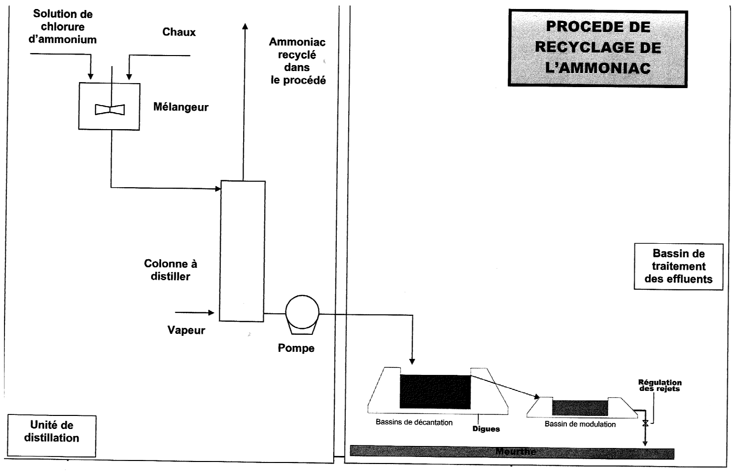
Settling basins

Transition basin

The involved units:

During the sodium carbonate production process, the “catalyst”, l’ammonia, enables the reaction of the salt with the carbon dioxide to form bicarbonate (a precursor of sodium carbonate) and ammonium chloride. This intermediate product reacts with both hydrated lime (from the liming operation) and vapour (distillation) in order to regenerate ammonia in gaseous form, which is then recycled at the process intake. This reaction, carried out in the distillation column, also produces a lethal by-product in the form of calcium chloride in solution; and this substance is eventually conveyed to the settling basins.

The distillation installations (intended to regenerate ammonia) and settling basins (intended to receive calcium chloride in solution) were the units involved in the incident that occurred on December 20, 2007.



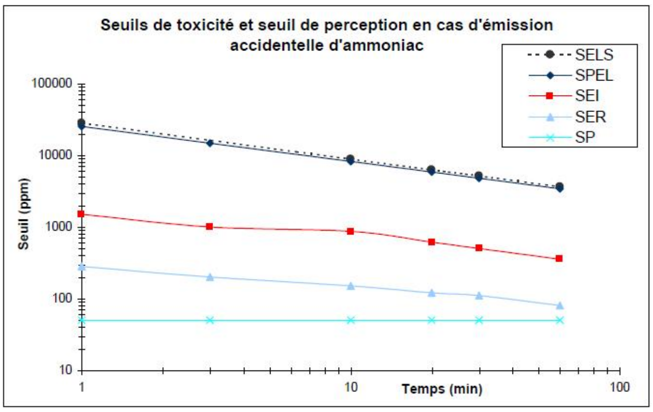
THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

The accident:

45 m^3 of ammonia-laden water, concentrated at a level of 22 g/l, originating from the distillation unit of the NOVACARB facility spilled between 7:20 and 7:35 pm into the plant's settling basins. The ammonia then slowly vaporised above the basins (at concentrations ranging from 50 to 60 ppm). The low temperature (-4°C) and stable atmosphere served to entrap the ammonia in a fog cloud that subsequently drifted slowly towards the outskirt of Nancy during the time frame of 7:35 to 10:00 pm.

As a reminder, ammonia gas is toxic when inhaled. For humans, the median lethal dose over a 4-hour exposure period extends from 700 to 2,800 ppm (i.e. 500 - 2,000 mg/m^3). The most acute symptoms are: vertigo, coma, pulmonary oedema and cardiac arrest leading to death. Depending on the victim, the irritation thresholds for respiratory mucosa and the eye vary between 50 and 100 ppm, while the olfactory threshold lies in the 5 to 25 ppm range. The gas has a pungent and suffocating odour, and the maximum exposure value at the workstation equals 20 ppm (i.e. 14 mg/Nm^3).

■ Courbes des seuils SELS, SPEL, SEI, SER et SP en fonction du temps d’exposition



SP : detection threshold

SER : reversible effects threshold / SEI : irreversible effects threshold

SPEL : first lethal effects threshold / SELS : revealing lethal effects threshold

Yet despite ammonia concentrations recorded in the middle of the cloud (10 - 30 ppm) below the irritation threshold, local residents complained heavily of the olfactory nuisance: between 7:35 and 10:00 pm, 600 phone calls were received by local police and fire-fighters. In all, over 1,000 calls notifying authorities of the incident were reported.

At 7:36 pm, the local Fire Services office (SDIS) and police, alerted by the high volume of calls from residents bothered by the smelly cloud overhead composed of ammonia vapour, proceeded by:

- requesting the intervention of emergency teams, which consisted of 24 fire-fighters and 8 SDIS vehicles, with backup provided by the adjoining department's SDIS unit and 5 two-person teams assigned to detect the presence of NH_3. Also called to the scene was a light-duty vehicle equipped with a sound system for notifying the local population to remain at home. In addition, an SDIS control room was set up at the Laneuveville-devant-Nancy municipal swimming pool;

- informing the Prefecture's Civil Protection agency (SIDPC), which assembled a crisis management committee at the Department's operations centre inside the Prefect's offices. This committee represented the various prefecture-level safety agencies (SIDPC, IIC and DDASS). Around 8:30 pm, the prefecture requested reopening the local radio station *France Bleu Sud Lorraine* to make broadcasts, within the prerogative of the crisis management mandate. The station was reopened at 8:45 pm and an initial press release, broadcast at 9:00 pm, advised the population living in the affected sector to remain indoors as a matter of precaution. Given the health risks involved and in recognition of the ammonia concentration measurement results, the length of confinement was purposely not mentioned in the release, which aired every 15 minutes.

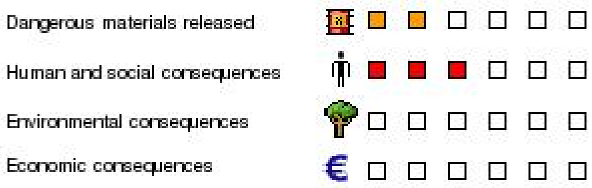
The incident ended around 10:00 pm, at which time calls from local residents began to taper off. Coordinated measurements in the field revealed a decreasing trend in concentration values, ranging between 10 ppm on the settling basin and in the sector around Laneuveville-devant-Nancy to 3 ppm over the city of Nancy's southern zone. A press release announcing the end of the crisis was issued at 11:00 pm on *France Bleu Sud Lorraine*. The crisis committee was adjourned at 11:30 pm.

The consequences:

In light of the low ammonia concentrations output during this incident, no victims were reported.

The European scale of industrial accidents :

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



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

Regarding the rating relative to hazardous materials, it should be noted that strictly speaking ammonia water at a concentration of 22g/l discharged by the operator is not, as a preparation, listed in the '*SEVESO*' directive. Nonetheless, this discharge still led to the release of approximately 1 tonne of ammonia gas, i.e. within 0.5% of the upper *Seveso* limit.

As for the rating relative to human consequences, the value N was estimated at 3,000, which corresponds to roughly 1,000 people being confined in their homes for 3 hours.

THE ORIGIN, CAUSES AND CIRCUMSTANCES SURROUNDING THE ACCIDENT

In the distillation column, the solution was composed of ammonium chlorides, calcium chlorides and various impurities capable of settling in the form of gypsum, which then encrusted the plant's devices and piping.

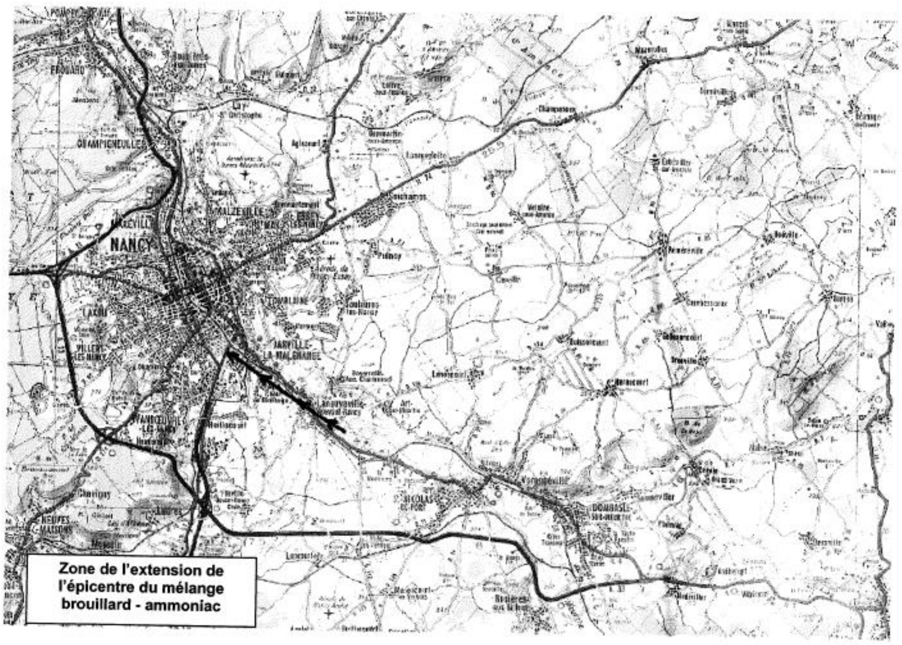
On December 20, 2007 during restart of a distillation unit, a piece of gypsum crust broke loose from one of the columns and clogged the suction chamber of the pump assigned to discharge saline effluent to the basins.

Gypsum crust

To allow the technician access to unclog this chamber, the effluent discharge pump was shut down. Since the solution supply to the affected column remained open, the column continued to fill until the liquid charge, which had become higher than the vapour pressure, could no longer be input to distil the solution contained in the column, meaning that the recycling reaction of ammonia could not proceed through to completion.

Once the gypsum clog had been removed at 6:50 pm, the effluent discharge pump was placed back into service. Insufficiently-distilled ammonia water kept being channelled to the settling basins for some 15 minutes before this anomaly was detected, sometime around 7:05 pm. Since the transit time for this volume of ammonia water (45 m^3 at a concentration of 22 g/l) through the plant's collector pipes heading to the basins equalled roughly 30 minutes, the polluted water overflowed at the level of the settling basin between 7:20 and 7:35 pm. The hot water from the column spread across the basin's 23-ha surface, above which the ammonia vaporised.

Given the meteorological conditions at the time (no wind, below-zero temperatures, high humidity) along with the inversion phenomenon caused by nightfall, the vaporised ammonia was entrapped by a thick fog layer several tens of metres high. The measurements taken by fire-fighters indicated that the air mass then shifted in a north-westerly direction, between 7:20 and 10:00 pm, with concentrations at the cloud centre dropping from 30 to 12 ppm. These concentrations were maintained throughout the cloud; moreover, during the entire incident, concentration levels remained less than the irritation threshold and considerably below the irreversible effect threshold.



ACTIONS TAKEN

On the day following the incident, in response to a request issued by the classified facilities inspectorate, the operator submitted a detailed report on the event, explaining its causes and listing the remedial actions necessary to avoid a repeat occurrence. This report was presented during the "Feedback" meeting held at the Prefecture on January 7, 2008, attended by the various State agencies involved in the incident (Prefect's Communication Office, SIDPC, DRIRE and DDASS), along with the SDIS and the operator.

A formal action plan drawn up by the operator, including a timetable, was sent to the classified facilities inspectorate by post on January 20, 2008. Subsequent to an onsite inspection conducted July 4, 2008, the updated action plan was filed once again by post on August 5, 2008, followed by additional materials sent on September 29, 2008.

It should be pointed out that around the time the incident took place, the safety study submitted by the operator in 2007 was being evaluated and had already given rise to a request for additional materials signed by the inspectorate in October 2007. In particular, the request was made to complete this study, so as to extend its field of application beyond ammonia tanks to include all plant installations. The new version of the site safety study, as mandated by Prefecture order on October 2, 2008, was filed by the operator on October 23, 2008 and is currently undergoing review by the classified facilities inspectorate, an agency set up within the regional Directorate for Industry, Research and the Environment (DRIRE).

LESSONS LEARNT

The action plan submitted by the operator contains the following improvement missions:

1- With respect to the organisation of emergency intervention:

- insertion of an "ammonia water leak" incident fact sheet into the internal emergency plan;
- availability of 10 ammonia detectors in the dedicated emergency cabinet, for fire-fighter use;

2- With respect to operations:

- operating procedure modification to include details of tasks and their sequencing;
- training provided to the five teams assigned to execute this updated procedure;

3- With respect to process monitoring:

- placement of an ammonia sensor at the level of the outlet distillation column effluent;
- adjustment of alarm threshold for the sensor currently placed at the basins;
- completion of a "what if" review and introduction of additional installation alarms and safety features.

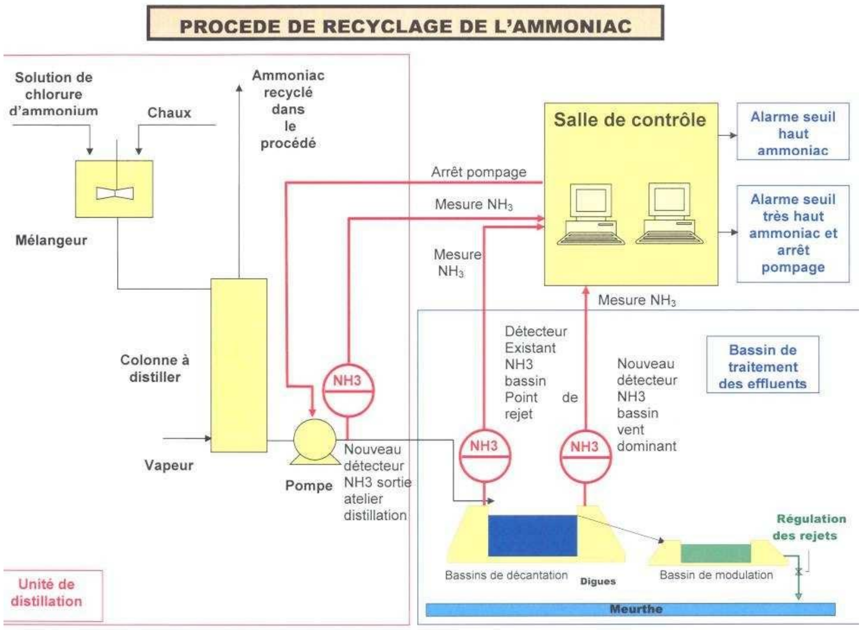


Diagram of process monitoring steps following the incident

In conclusion, it will be remembered that this incident, despite giving rise to a hazardous phenomenon of low intensity (i.e. dispersion of a cloud whose concentration remained considerably below the irreversible effect threshold for humans) and introducing into the atmosphere substances considered as non-hazardous (a weakly-concentrated ammonia solution), did stir the local population to a point of deploying an emergency response organisation identical to what a much more serious accident would have necessitated.

As a closing remark, this incident arose as a result of both unfavourable meteorological conditions for cloud dispersion and poor execution of a maintenance procedure at the specific time in the process when ammonia is used. Until this incident, only ammonia storage installations had been the topic of safety studies performed by the operator. Moreover, the need to conduct a safety study whose field of application focuses on all hazards associated with the entire array of installations within a facility appears to be the primary lesson drawn herein. This lesson serves to corroborate the measures adopted in the May 10, 2000 modified Ministerial decree, as well as those stipulated in the September 25, 2005 decree and its accompanying administrative memoranda.

Closing remarks

Laurent MICHEL
Managing Director, Risk Prevention Directorate

Greetings to all,

I have the distinct pleasure of drawing to a close what has now become a regular seminar on industrial accident analysis. This 8th edition has fulfilled all its promises: a new attendance record was set with a total of 263 participants representing 18 nations, 16 of them from the European Union and the other two close neighbours, as well as the UNECE Commission. This two-day session saw an intense flurry of activity centred around a dense seminar agenda with no less than 21 events analysed, including a greater proportion of incidents arising outside of France: half this time vs. just a third during the previous seminar.

These trends confirm the strong interest and need for such exchanges in the area of accident analysis in order to advance in the field of risk prevention and meet the various challenges assigned to facility inspection authorities.

I would like to thank all seminar speakers for their thorough and highly-instructive presentations, as well as the entire audience for their insightful questions and comments that helped round out these proceedings; thanks are also addressed to session presidents who organised the roundtable discussions, the Paris Region's DRIRE Agency and its Director Bernard DOROSZCZUK for the quality of seminar reception and organisation services, and not to overlook BARPI's outstanding efforts in the areas of technical preparation and analytical materials.

Without returning to the highlights from our many series of exchanges over these past two days, I feel it useful at this point to underscore four specific points.

The first point to be emphasised: the ageing of installations. This trend had already been exposed in our previous gatherings. Some facilities were built several decades ago and a good number of major accidents are related to the ageing of Europe's industrial infrastructure: a silo collapse, oil tanks ripping open, corrosion or rupture of pipelines, just to name a few... We must be focusing our efforts on the most critical installations via a process that: appropriately identifies such installations, solicits initiatives from professionals, strengthens regulations, and improves control over the diagnostic and maintenance tasks. We must have the drive to reduce this risk, yet fully aware that it can never be completely eliminated. For this reason, it is necessary to offer the possibility of detecting these hazardous phenomena and limiting their magnitude or consequences should, in spite of all the precautions taken, an accident still occur.

Which leads to my second point: the need for a comprehensive approach. From this perspective, continued heavy emphasis on expanding prevention measures must rely on improving "SGS" and enhancing preparedness for the eventuality of an accident. The purpose here is to develop a multifaceted approach covering prevention, exposure limitation for both humans and the environment, response and crisis management, all designed to remain in effect until normal operations can be restored, while at the same time ensuring information dissemination to society and providing the maximum amount of input into the decision-making process.

Within this comprehensive approach, a number of questions have over the course of our seminars taken on increasing importance and must now serve to guide our action. I'd like to share with you some of these details to help illustrate the point:

- First of all, the occurrence of natural triggering events at greater frequency and intensity as a result of climate change: examples include SEVESO sites considered to lie outside the flood zone yet which wind up being flooded. Along the same lines, several recent storms have undoubtedly stimulated a renewed and altered assessment of the impact of natural hazards and their interaction with technological risks.

- Another illustration: a working group is currently assembled in France, with the aim of developing a strategy towards maritime risks. One of the questions brought before this group concerns the possibility of an industrial or nuclear site becoming submerged as a result of sea level rises. Are we entirely prepared to confront these risks over the coming decades?

- Next, the organisation and management of onsite works. Here is a recurring topic that, statistically speaking, represents a considerable number of accidents and over a third of the cases presented during our two days together. Special attention needs to be paid by site operators, as well as inspection authorities, to conducting complete verifications including: adequate risk analysis, information disclosure to onsite subcontractors, accountability, commitment of executive staff, site monitoring, and safety measures.

- I'd like to take a moment to discuss mitigation and intervention. The occurrence of major accidents demonstrates that the low estimated probabilities derived from risk analyses must not serve as a pretext for restricting efforts to prevention alone. These analyses need to be treated in greater depth to avoid being ill-prepared or unresponsive should an accident happen.

- I'd also like to address the issue of environmental consequences stemming from accidents as well as their monitoring. This scope extends beyond immediate consequences and becomes more readily apparent when discussing technical concerns, and in the queries received by members of civil society, which once again do not always target the most widely expected sites. The Ministry and one of its regional directorates are presently grappling with the consequences of an extensive fire, which after smouldering for months dispersed various organic pollutants over a zone several kilometres in radius. Animal fodder along with the milk and meat from cows were contaminated and banned from consumption. Compensation and costs for a range of remedial work, with a price tag reaching into the millions of euros or perhaps tens of millions, have had to be paid out for a site that wasn't even classified SEVESO.

The third key point concerns the considerable social aspects related to the issue of industrial accidents and their prevention. Over 70% of the cases analysed during this seminar have clearly highlighted the need for strong public communication on a wide array of situations: fire, discharge of toxic or malodorous substances, pollution of coastlines or border rivers, etc. The risk prevention community - encompassing site operators and authorities, each representing their field of specialisation - must take into account this social component in their policy decisions and even more so in their actions.

It is crucial to keep the local neighbourhood informed in real time whenever nearby industrial installations experience incidents or accidents, to avoid alarming the population unnecessarily or spreading rumours. This approach should also provide the opportunity to develop, in conjunction with civil society, a dialogue on prevention limitations and their consequences so as to encourage civil society participation in the decision-making process.

Risk prevention is not solely the realm of specialists; the decisions it implies overlap with many aspects of residents' day-to-day lives, including: lifestyle considerations, planning issues, health, the economy and employment. Experience has already shown that our decisions generate a much more solid and durable framework when based on the broadest consensus possible.

The final point I'd like to raise deals with the benefit of mixing approaches to the various risk prevention disciplines. Beyond SEVESO classified facilities, our examinations of accidents may be extended to other sectors, such as pipelines carrying hazardous materials or gas distribution lines, the transport of such materials by road, rail or water, as well as mines, underground storage sites, dams, etc.
The objective here is to share experiences for the purpose of minimising the chance of repeating the same mistakes and advancing more quickly and at lower cost. The overlap of approaches by actors involved in these fields will enhance efforts by both control authorities and facility operators.

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In conclusion, I hope that this seminar has met your expectations. This type of European forum provides information and feedback in order to better analyse safety reports, regulate and inspect installations and especially their operations, since once approved to start operating, the possibilities for malfunctions are multi-fold and close monitoring of technical as well as organisational measures becomes essential.

This seminar has stimulated lots of exchanges and contacts within the IMPEL network to help us in tackling the challenges of our professions, which outside of their cultural specificities contain many common features. It is vital that such exchanges continue to be nurtured without waiting for the next gathering since mutual progress depends on the strength of our ties.

Before wishing you the best of success in your prevention and inspection efforts, I would kindly ask each of you to submit your evaluation and suggestion form in leaving the auditorium. This valuable feedback will allow us to better fulfil your expectations when organising our next seminar towards the end of 2010, which you are all cordially invited to attend.

Thank you all once again for your spirited participation during these past two days, amidst a most friendly atmosphere that surely contributed to the event's success.

- Analogies -

The studies of the 21 accidents made by the inspectors of the IMPEL network and the lessons learnt from them are written down in reports produced in the previous chapter. They enabled to touch different recurrent issues of the industrial accidentology.

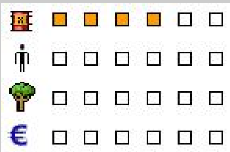
For each one, the European inspectors could refer to synthesis illustrated on technical and organizational levels with a number of similar accidents recorded in the ARIA database. The corresponding synthesis are given in the following pages.

Floating roof

① Accidental discharge of gaseous hydrocarbons

ARIA 33335 - 18/07/2007 - 76 - PETIT-COURONNE

19.20 - Petroleum refining



The sinking of a double-deck floating roof on the 70-m diameter B962 tank containing over 62,200 m³ of crude oil was detected on July 18, 2007 in a refinery. No product had been transferred from this tank since July 2, the day of the most recent filling. Monitoring of the tank level had revealed abnormal variations beginning on July 5. The level of liquid in the container was read at 14 m when the sinking roof was first remarked, causing 3,850 m² of surface area of crude to enter into direct contact with the ambient air.

The facility operator logged the tank's electrical supply and verified the hydrocarbon vapour concentration every 2 hours at the site of the retention basin. An emergency fire-fighting vehicle from the refinery's fleet was positioned along the edge of the basin ready to intervene. A series of hydrocarbon concentration measurement sensors installed in the town of Petit-Couronne recorded very high concentration levels (between 10,000 and 25,000 µg/m³), yielding an average background noise of 1,500 µg/m³.

The Hazardous Installations Inspectorate noted these facts. The operator proceeded with a gravity transfer of tank contents into other refinery tanks until the liquid level neared that of the roof, which had stabilised at 2.8 m. The tank shell was then punctured at high pressure and water injected into the tank to enable removing the remaining hydrocarbons by means of pumping. Drainage operations continued for several weeks in order to extract via a bottom outlet all liquid contained inside the tank along with the sediments that had settled.

The operator estimated the quantity of volatile organic compounds (VOC) emitted into the atmosphere during these tank drainage and safety prevention steps at more than 3,000 tonnes, including approximately 55 tonnes of benzene.
While awaiting the final results of investigations performed at the time the roof was disassembled, the initial findings released by the operator tend to support the hypothesis of a loss of flotation capacity due to overload caused by both the accidental filling with crude of a leaky caisson and the accumulation of rainwater on the roof. The foot valve on the rainwater discharge trough had been closed, subsequent to the detection a few months prior of hydrocarbon leaks inside the discharge drain.

Renewed use of the tank following repairs has been scheduled for the end of August 2009.

Floating roof

Installed directly at the liquid surface, the floating roof of a storage tank enables reducing the evaporation losses of certain products via the vapour portion and thereby limiting the chronic atmospheric releases generated by the most volatile products. These economic and ecological advantages have contributed to the widespread development of floating roofs, in particular for storing liquids with high vapour pressure, such as some crude oils, naphthas or gasoline. Accident statistics held on floating roof tanks confirm the necessity of closely monitoring operations and maintenance, especially given their tendency to have large capacities in addition to their more sophisticated designs.

The phenomenon of roof submersion by the product contained within the tank has been observed on a considerable number of occasions (ARIA 1514, 22491). A lateral or rotating motion, excessive tilting or sticking can lead to a loss of liquid tightness between the roof deck and the tank shell significant enough to allow the liquid to submerge the roof (ARIA 22491) and in some cases cause the roof to sink (ARIA 10208, 22325). The seepage of rainwater or stored product into one or more roof caissons subsequent to a faulty seal can also produce either total (ARIA 33335) or partial (ARIA 34360) roof immersion.

The filling phases are particularly sensitive to this type of event (ARIA 10208, 22325, 22490), since the roof moves vertically in sync with the rising level inside the tank. In addition to enhanced monitoring, special attention needs to be paid to both the filling rate and effective operations of onsite prevention equipment (level alarms, speed limiters, etc.). In some instances, roof submersion is accompanied by fire whose ignition has been facilitated by the presence of vapours that become combustible when in direct contact with air (ARIA 6277, 22325).

Roof immersion in the liquid is not the only situation where a highly-inflammable vapour portion forms above the roof. Besides faulty seals at the level of the peripheral joint (ARIA 20819), corrosion-induced leaks (ARIA 34360) or cracking may appear within the roof structure itself.
The vapour portion is thus capable of igniting and causing serious accidents. In 1983 in Milford Haven (ARIA 6077), the ignition of vapours escaping through cracks some thirty centimetres long localised on the membrane of a single-deck roof of a light crude tank led, by extension of the initial defect, to a tank "boilover" and the destruction of several adjacent tanks. More recently in Skikda during 2005 (ARIA 34130), the combustion caused by a vehicle of a gas cloud, which had formed above the floating roof on a crude oil tank and then gathered over a lower elevation zone, caused an enormous fire, the deaths of 2 plant technicians and tremendous outpouring by the local population. Besides installing detection devices, the effectiveness of the initial emergency response can prove determinant in containing the spread of the blaze (ARIA 27990, 6077).

Large storage tanks are exposed to an aggressive atmosphere, and many events affecting floating roofs arise during or after periods of severe climatic conditions: violent winds, in one instance fanning the flames on the floating roof of a tank in Finland containing hexane (ARIA 134), while in another contributing to crack formation in the roof structure at Milford Haven (ARIA 6077); snow causing a roof in Essex (U.K.) to sink (ARIA 22325); frost leading to the failure of a flange joint on the stormwater drain in Carling (ARIA 10331); heavy rain accumulation resulting in tilting (ARIA 32340), or in Petit-Couronne to the actual sinking of a roof (ARIA 33335) due to an inefficient stormwater discharge system.
Tanks equipped with a floating roof are also vulnerable to the impact of lightning. Fire often breaks out at the level of the roof air seal (ARIA 6277, 20819, 20587) and sometimes extends throughout the tank (ARIA 27990). The quality of the shell/roof equipotential bond, grounding and the seal around the joint (ARIA 12229, 12231, 20819) all constitute efficient preventive measures for coping with this risk.

Several cases of accidental discharges of the product contained in tanks have been recorded in ARIA, and these generally stem from a defect or malfunction in the drainage system for rainwater collected on the roof. Such equipment plays a key role in the mechanism for confining the product inside the tank. A deficient seal on the stormwater drainage line causes the product to penetrate into the line (ARIA 22293, 26740), followed by product flow into the retention basin associated with the tank (ARIA 10207, 34360) or, in some cases, into a collection pipe network (ARIA 34360). Except for the case where the retention device displays a poor quality seal (ARIA 26740), the products may be recovered in the basin, and in general this type of incident does not yield serious consequences.

Regardless of the facilities involved, works performed tend to generate specific risks that would need to be analysed in order to determine the appropriate means of prevention. The potential presence of vapour on a floating roof complicates all operations carried out in the vicinity of the roof (ARIA 19534), especially in the event of incandescent projections. Even after draining and degassing the tank, any hot spot activity on a floating roof introduces a set of risks specific to the potentially inflammable nature of the atmosphere inside or immediately adjacent to a tank (ARIA 8988).

Accident analyses have revealed a wide array of scenarios leading to incidents and accidents involving floating roofs with potentially sizeable human, social, environmental or economic impacts. Such analyses underscore the need for permanent and reinforced supervision of the proper operations of all devices placed into service (roof position and absence of liquid at the surface, filling phases both during and after the occurrence of extreme climatic conditions), yet with even greater emphasis on detailed controls and strict maintenance (overall state of repair of the roof deck, efficiency of the joint and the stormwater drain, close monitoring of all works conducted).

The accidents whose references are not underlined may be consulted at:
www.aria.developpement-durable.gouv.fr

ARIA 134 - 23/03/1989 - FINLAND - PORVOO

19.20 - Oil refining

A hexane leak occurred above the floating roof of a 30,000-m³ tank 52 m in diameter and 14 m high. Despite application of a foam layer, ignition occurred the following day. The fire was extinguished within 50 min, but a break of the foam film caused by wind (blowing at 20 m/s) led to re-ignition after another 52 min. The second fire required 27 hr to extinguish, once the product had been transferred, necessitating the deployment of 509 rescue workers and the consumption of 200 m³ of emulsifiers.

Total damage was estimated at 30 million Finnish markka. 15,000 of the 22,000 m^3 of hexane contained inside the tank burned during the fire.

The hypothesis of ignition triggered by static electricity discharge has received the most support.

ARIA 6077 - 30/08/1983 - UNITED KINGDOM - MILFORD HAVEN

19.20 - Oil refining

In the storage tanks of a refinery (production: 5 million tonnes/year), smoke was detected on a 94,000-m³ capacity floating roof tank containing 47,000 tonnes of light crude oil (flash point: 38℃). Shortly thereafter, the surface (4,800 m²) ignited. In the absence of a fixed protective device, the emergency response team projected foam at the tank roof using a gun mounted on an aerial platform, while protecting the adjacent tanks and cooling the walls of tank no. 11. The roof collapsed (with an estimated roof load equal to 700 tonnes). A few hours later, the requisite resources were in place: 26 pumps, 11 cisterns, 6 hydraulic platforms, and a crew of 150 fire-fighters. In conjunction with this response effort, the crude was being drawn out (at a rate of 1,700 tonnes/hr) in order to lower the tank level. A full-scale foam attack was deemed necessary, although the emulsifiers had not yet been installed; 160 m³ of the total 200 m³ were considered the minimum necessary. An emulsifier collection plan was thus launched. The rate of oil burned in the tank by fire was estimated at 300 tonnes/hr. The nearby tanks (2), which had been exposed to strong thermal radiation, had to be drained (as a result of heat insulation damage). Tank no. 11 started bubbling in its upper part and gradually subsided. 12 hours after the incident began, a boilover occurred and created a fireball (radius: 90 m; height: 150 m). Fire-fighters, surprised by the magnitude of this fireball, had to find refuge and regroup. Two vehicles were destroyed, standing pipes melted and had to be reinstalled (due to incompatible fittings). The tank overflowed, with fire propagating into the basin. Six fire-fighters were injured. 2 hours and 10 minutes later, a 2nd boilover happened. The shell/bottom bond on tank no. 11 broke in four places: fire spread throughout the basin (covering an area of 16,722 m²), bordered by 5-m dikes that were able to resist. At this point, fire-fighting crews feared a 3rd boilover and mounted a foam attack (with a flow rate of 1,773 m³/hr). A water cannon (operating at 13.6 m³/min) was introduced to improve positioning. At 2:00 am the following morning, the fire had spread once again, this time over the entire tank surface. Once the additional emulsifiers had been delivered, the fire could be controlled around 3:00 pm (over 60 hr after detection). A total of 765 m³ of emulsifier proved necessary. Causes of the accident were found to be: presence of cracks and traces of light crude on the tank roof (38℃ flash point); same-day use of the flare system (height: 83 m, distance to tank no. 11: 99 m) following malfunction of the catalytic cracker compressor; and projection of incandescent carbon particles on the oil that had spread onto the single-deck tank roof. The cracks (which had undergone recurrent repairs) were due to fatigue from exposure to the region's gusty winds. The operator had only anticipated, for floating roof tanks, the scenario of a joint catching on fire. The lack of fixed protective devices (sprinkler ring, foam box), appropriate mobile response equipment and emulsifier postponed and complicated the response, which in turn exacerbated the disaster.

ARIA 6277 - 05/11/1994 - 13 - BERRE-L'ETANG

19.20 - Oil refining

The floating roof of a 15,000-m³ storage tank containing platformate (a mixture close to that of gasoline) sank for an unknown reason. This immersion was detected on November 5 at 9:40 pm. Despite spreading the foam in an effort to prevent fire, lightning caused the product to ignite on November 7 at around 9:45 pm during a violent thunderstorm, once the foam layer had been weakened by the downpour. The fire was contained within 40 min through deploying in-house response teams. The volume of hydrocarbons destroyed in the fire was estimated at 400 m³; moreover, 25,000 litres of emulsifiers were consumed. Property damage estimates amounted to 2.2 million francs.

ARIA 8988 - 30/05/1996 - 76 - LE HAVRE

52.10 - Warehousing and storage

Three employees of a maintenance firm were repairing the floating roof of an empty 30,000-m³ gasoline tank, which prior to these works had been insulated, degassed and washed, when a flash type explosion occurred. The Internal Emergency Plan was activated. The workers were able to escape, but their vehicle was set ablaze. Pieces of the roof were projected some 100 metres. Fire-fighters used water to cool the pipes and adjacent tanks; during their intervention, they noted the poor quality of available emulsifiers. The fire extinction products had remained in the basin. It took roughly 10 min to extinguish the fire. Close monitoring extended throughout the night, and the order was issued to cease all similar works. Total property damage was assessed at 9 million francs.

ARIA 20819 - 01/01/1999 - TUNISIA - BIZERTE

19.20 - Oil refining

A fire broke out on two gasoline reservoirs with floating roofs. The reservoir joints were not properly sealed. During a thunderstorm, lightning ignited the gasoline vapours emanating from the leaks. The fire was controlled by rescue teams in 30 to 40 min. The reservoirs were heavily damaged, and a significant quantity of gasoline was lost (several thousand m^3).

ARIA 22325 - 26/02/1991 - UNITED KINGDOM - ESSEX

19.20 - Oil refining

Inside a refinery depot subsequent to mishandled supply of a tank containing 7,000 tonnes of naphtha (and perhaps also due to the weight of snowfall), the tank's floating roof became immobile and then sank. A technician sprayed foam onto the tank in order to limit evaporation of the product, but the foam was applied erroneously (as a result of inadequate training/instructions/procedures for emergency situations) in the middle of the tank surface rather than at the periphery. The static electricity charges produced then ignited naphtha/air vapours. Given the low ambient temperature (0℃), flash was not produced and the vapours ignited progressively as they were being released. The site's emergency response plan was triggered, and both internal and external rescue teams fought the fire for 3 hours before its extinction. No impacts could be observed on the environment. Following this accident, the set of communication procedures as well as instructions and training on static electricity charges underwent revision.

ARIA 22490 - 17/07/1999 - GERMANY - KARLSRUHE

20.1 - Manufacturing of basic chemicals, nitrogen products and fertilisers, basic plastics and synthetic rubbers

While making rounds at a storage tank facility, a watchman noticed a smell of crude oil. Since this observation coincided with filling a storage tank with crude, a fellow employee inspected the tank and reported that the floating roof was entirely covered by crude. The initial measure adopted was to halt the ongoing tank supply. For safety and environmental protection reasons, fire-fighters spread out a foam carpet. Hydrocarbon and H2S measurements taken immediately thereafter did not indicate any noticeable concentrations. Only a slight odour could be perceived at the site before foam was implemented throughout.

ARIA 22491 - 09/06/1999 - GERMANY - KARLSRUHE

20.1 - Manufacturing of basic chemicals, nitrogen products and fertilisers, basic plastics and synthetic rubbers

Gas discharge occurred at a storage tank facility. The subsidence on one side of a floating roof (approx. 10° incline) caused a momentary release of fumes (gasoline and thiols). In a span of 8 hours, the roof completely collapsed. Any release of gases could be avoided by application of a foam cover, and the tank was then emptied. The event was detected from the odours produced. Fire-fighters set up a wide safety perimeter, covered the foam liquid and proceeded with analyses that turned up nothing abnormal. This incident caused nausea among a few of the individuals on or near the site.

ARIA 26740 - 29/12/2003 - 67 - REICHSTETT

19.20 - Oil refining

On the hydrocarbon storage site at a refinery, a 50-m^3 leak of aromatic hydrocarbons was identified on a 10,000-m^3 vertical tank with a floating roof. The discovery was made by a technician during a sampling step conducted when transferring the product to a manufacturing unit. The technician stopped this flow by closing the drain valve. A portion of the hydrocarbons was held in the retention ring, while the remainder spilled out into the retention basin (presence of two stains 10 m^2 in surface area on the ground) and infiltrated. The hydrocarbons contained inside the ring were then pumped. The operator shut down the specific tank in the aim of completely draining and degassing it to enable additional investigations (to determine origin of the failure and the type of repairs needed). Moreover, he installed a pump operating at 40 m^3/hr in a pre-existing shaft, located approx. 30 m upstream of the pollution in order to contain potential groundwater pollution. This measure was accompanied by tracking the evolution in pumped water quality. Two days later, the industrial owner noticed the first traces of hydrocarbons arriving in the control well. He called upon the services of a hydrogeologist to assist in taking additional measurements. According to the site operator, the leak stemmed from a failure of the stormwater drain system installed on the floating roof located inside the tank; hydrocarbons were discharged via the drain valve at the bottom of the tank in the surrounding retention ring. This valve, in the normal position, had to stay open to allow for rainwater to flow from the floating roof. Furthermore, the operator was responsible for identifying those tanks on the site whose equipment had been identically configured: a single tank fit this condition and was shut down while awaiting verification inspection.

ARIA 27990 - 20/06/1987 - UNITED STATES - NC

46.71 - Wholesale of fuels and accessories

In a liquid hydrocarbon storage facility, fire broke out on a floating roof tank (12-m high) containing 9,300 m^3 of unleaded gasoline (filled to the ¾ level). Lightning was the cause of this accident. Since the tank had not been fitted with fire-fighting equipment, the safety team elected to fight the fire with a hand-held hose from the truss atop the tank shell: the fire engulfed approx. 20% of the total circumference yet could not be contained by fire-fighters at the site, who were forced to withdraw. The fire spread over the entire roof, which ultimately sank; the tank was destroyed and damage was estimated at USD 10 million.

ARIA 34130 - 04/10/2005 - ALGERIA - SKIKDA

19.20 - Oil refining

An explosion followed by a fire occurred around 10:00 am on a tank with a nominal capacity of 51,000 m^3 containing 35,000 m^3 of crude in an oil terminal; the fire quickly spread to an adjacent tank. The inflamed crude then generated a tremendous blackish cloud over 200 m high standing above the petrochemical operations platform and the neighbouring city.

The automatic tank extinction system malfunctioned and emergency team organisation and coordination problems complicated the task at hand: 5 fire-fighting vehicles parked too close to the first tank caught on fire and were totally destroyed by the flames. No measures were adopted to ensure the safety of the nearby population, many of whom panicked and fled the town.

It took 8 days for the fire to be fully contained. The human toll was a heavy one: 2 deaths and 7 injured, with financial losses assessed between 5 and 6 million dollars.

According to the conclusions drawn from the investigations conducted, inflammable gases would have formed above the tank's floating roof and accumulated at a lower elevation where an internal access path ran. After having stalled due to a lack of oxygen, the engine of the vehicle in which the 2 company employees died started up again and ignited the gas cloud, spreading flames towards the top of the tank.

Six executives working with the oil rig were sanctioned for non-compliance by senior company management, and another 6 who participated in demonstrations held by the local population were fined and convicted with a suspended sentence.

ARIA 34360 - 17/01/2008 - 13 - MARTIGUES

19.20 - Oil refining

Around 11:00 am, the arrival of a major delivery of liquid hydrocarbons was recorded at the preliminary sedimentation basin of the refinery's waste treatment plant.

A technician noted the presence of product on the floating roof of tank CU15 containing "FCC gasoline", with a gravity runoff system passing via the stormwater collection drain on the roof in the direction of the oily water collection network. The drain was isolated and the tank was first drained then filled with water.

The personnel present near the treatment plant were evacuated from the site's basin zone as a precautionary measure due to strong hydrocarbon odours, while measurements of both COV and benzene content in the atmosphere were conducted: results proved to be negative. After cleaning, the plant and collection basin were placed back into service.

The quantity of FCC gasoline released was calculated at 40 m^3.

The operator had identified external corrosion on the upper shell of the double-deck floating roof. Rainwater had infiltrated into the central caisson and subsequently overflowed into two other caissons. The roof tilted and wound up being partially submerged (less than 10% of its surface area).

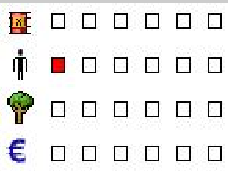
The operator has been studying the possibility of installing a hydrocarbon detector on the basin's oily water drain in order to prevent any accidental inflow of hydrocarbons into the treatment plant.

Transport of waste in tank trucks

② Accident involving a tank truck transporting waste

ARIA 33767 - 31/07/2007 - 78 - LIMAY

22 – Treatment and elimination of hazardous waste



In an industrial waste treatment centre, the cover of a manhole on the back face of a tank truck ruptured due to overpressure resulting from the decomposition of the waste contained in the truck. The tank degassed abruptly. The truck moved 15m forward and the cover was projected onto the siding of a hydraulic plant. The tank truck and the waste dispersed in the surrounding area were sprayed with water for 30 min to bring their temperatures down. The operating staff was evacuated from the accident zone and the administrative staff required to stay indoors. The water used to cool the tank and the waste was collected. An employee of the site sustained partial burns on his foot.

The waste responsible for the accident was a mixture of 30% hydrogen peroxide and 5% resin acids. The accident resulted from a transfer error that occurred on 29 May 2007 in a paper mill where the waste was produced. The waste was received in the treatment centre on the day before the accident for incineration. The operator faced problems in extracting the waste from the tank and observed a rise in the external temperature and internal pressure in the tank. The tank was sprayed with water from 8.30 am. Water curtains were used around 12.30 pm and finally fire nozzles at around 1.30 pm. The abrupt degassing occurred around 2.30 pm.

The analysis of the accident shows several failures: shortcomings in the waste acceptance process, transformation of the waste between the time of transmission of sample by the customer and reception of waste in the centre, no checks on temperature for manholes and vents on reception of the tank truck, etc.

Transport of waste in tank trucks

The Limay accident shows the risks involved in collecting, sorting, mixing and transporting liquid wastes.

Besides their nature, unlike pure products waste can be “sensitive” as their physico-chemical properties are not clearly identified. The risks involved result from the dangerous, sometimes sudden and violent, chemical or biological reactions that occur accompanied by abrupt increase in temperature (ARIA 4460, 4859, 10621, 15096, etc.) enhanced by the possible insulation of the container (ARIA 4460, etc.), masse polymerisation, production of significant volumes of gaseous reactants mainly through hydrolysis (ARIA 12062, etc.), gas emissions from the tank truck manhole or valve (ARIA 4859, 10621), even explosion of the tank (ARIA 1159, 4460), etc.

The 11 accidents from the Aria database enclosed in the annex thus bear out the crucial role played by organisational and human factors in the corresponding accidents.

Before sorting and mixing residual effluents or liquid waste in a fixed storage tank, and even more so in a tank truck (agitation during transport, absence of cooling device, etc.), it is crucial to ensure that the physico-chemical properties of the collected waste are perfectly compatible with those of the material constituting the tank truck (ARIA 4460, 12164, 20095, 34465, etc.). The transformation of the waste must be constantly monitored throughout the treatment chain: error in identifying and mixing incompatible products (ARIA 15096), unforeseen presence of a toxic gas (ARIA 4637, 32574, etc.), unsupervised transformation in the properties defined at the time of identification of waste (ARIA 33767, etc.), inappropriate “treatment” infrastructure or transfer process (ARIA 12062, 32540, etc.), etc.

While transferring substances, the open vents of fixed or mobile tanks (ARIA 4460) must be connected if required to an adapted residual gas collection and treatment devise since all persons not directly involved in the operations are prohibited from entering the transfer zone between the tanks (ARIA 32574, 4637, etc.).

Lastly, special care must be taken in the upkeep of the transport vehicle: hydraulic tests not performed, engine oil leakage (ARIA 34236), tank truck not properly cleaned between two transport operations (ARIA 20095, 29942, etc) are all causes of accidents.

The most serious accidents involving transport of waste by tank trucks and that have resulted in deaths attribute the cause to toxic gases including fermentation effluents. Technicians carrying out the transfer operations are the first victims, followed by persons attempting to rescue them without adequate protection and ignorant of the exact causes and circumstances of the accident (ARIA 4673, 31000, 32574, etc.).

Smoke from fires (ARIA 15844, 19078, 20063, etc.) as well as fallouts from the projection of dangerous substances in the air (ARIA 1159, 4460, 7833, 15096, 34236, etc.) can help assess the nature and impact of toxic, polluting or hazardous substances at various concentrations on the surroundings, as well as the extent of the polluted areas before implementing safety perimeters, reducing water and food, cleanup operations, etc.

Besides the hazardous nature of the transported material, non-compliance with basic waste management procedures and more generally inappropriate safety provisions result in the majority of such accidents. To bring down the number while reducing the consequences, several recommendations may be put forward pertaining to:

- ✓ Properties of the substance in question (pH, temperature, colour, viscosity, odour, etc.), controls and tests ensuring chemical compatibility between substances, ensuring absence of phases and any immediate and sudden chemical reaction or transformation in the properties of the substance in time in the mixture;
- ✓ Defining and laying down responsibilities and adapting them to all operations to be performed by subcontractors until the treatment site;
- ✓ Training technicians to manage encountered risks especially the ones related to unloading or transfer operations of substances (possible presence of toxic or inflammable residual gases, etc.);
- ✓ Defining measures to be taken in the event of an accident or incident, implementation of detection, surveillance and corresponding mitigating devices and measures;
- ✓ Documentation of all procedures right from receipt of hazardous waste to its elimination with reference to critical safety parameters and properties.

Additional references (detailed sheets):

- ARIA 4637_grasse_1993 / Emission of H_2S in the end of transfer of liquid waste from a tank truck
- ARIA 22170_persan_2002 / Emission of HCl while emptying a tank unused for several years.
- ARIA 31000_rhadereistedt_2005 / Emission of H_2S while unloading slaughter waste from a truck.
- ARIA 32574_stuttgart_2005 / Release of H_2S from the vent of a tank truck in a waste treatment plant.

The accidents whose references are not underlined may be consulted at:

www.aria.developpement-durable.gouv.fr

ARIA 1159 - 01/04/1989 - 38 - SALAISE-SUR-SANNE
38.22 – Treatment and elimination of dangerous waste
While emptying a tank truck at an industrial waste treatment site, an explosive reaction occurred after several kinds of chemical waste were mixed. Material damage was significantly high and five people sustained slight injuries.

ARIA 4460 - 27/04/1993 - 84 - SORGUES
20.51 – Manufacture of explosives
On 19 March, a tank glazed with 85% H_2SO_4 ruptured leading to a workshop to close down for five days. Given the waste acid storage autonomy period of four days for production, 3 tank trucks hired in February and not dispatched following a leak in the waste acid tank were reused and three additional tank trucks were hired. Tank truck 2 was half filled with waste acid from the production of dinozebe on 26/02, and completed on 23/03 with waste acid from the production of DNTCBB (dinitro 2-6 tertiobutyl 4 chlorobenzene), a crop protection intermediate. On 27/04, nitrous vapours were emitted from the manhole of tank truck 2. The internal contingency plan was triggered. The insulated tank truck was cooled with water hose nozzles. A water curtain was used to disperse the nitrous vapour cloud that was 30 m high and 180 m long. The tank truck exploded since the situation was aggravated by its insulation and closed vents. An acid aerosol was projected over 135 m, metal debris of 3 kg reached 195 m and 15 m³ of matter was spilt on the ground. Two technicians affected by the accident at the boundary of the site were treated onsite. Despite the projections, three lifeguards located at 25 m remained intact. Ground pollution in the town of OUVEZE was limited and the spill was neutralised with calcium carbonate.After an enquiry was conducted, it was shown that at room temperature and under adiabatic conditions, dinozebe starts to decompose after 15 days of contact with waste acids from the production of DNCTBB along with the formation of nitrous vapours. There was a slow decomposition reaction between the contents of the tank truck and the trace dinozebe during the month of storage accompanied by an increase in pressure of the airtight and insulated tank truck. The accident resulted from inadequate cleaning between the two uses and the mixing of incompatible materials that triggered the sudden reaction. Measures were taken for other tank trucks containing the same acids: opening of manholes, cooling devices for tank trucks, etc. The use of temporary mobile storage containers without retention tanks was not allowed. Furthermore no risk assessment studies were carried out on the storage and treatment of waste acids. Material damage was evaluated at 0.36 MF.

ARIA 4637 - 07/07/1993 - 06 - GRASSE
20.14 – Manufacture of other basic organic chemicals
At the end of transfer operation involving concentrated liquid waste, a tank truck driver collapsed after closing the vacuum pump circuit. A voluntary fire-fighter took ill and had to turn back. The driver died soon after. Hydrogen sulphide (H_2S) was undoubtedly released at the end of the transfer. The inspection authorities of classified facilities noted that certain specific procedures had not been followed.

ARIA 4859 - 29/06/1993 - 52 - BOLOGNE
49.41 – Road transport of freight
Gas emissions were released from the manhole of a tank truck transporting acid waste (mixture of chromic and sulphuric acid). The resulting exothermal chemical reaction was brought under control by cooling the tank truck. The vehicle then continued with its journey to the treatment plant.

ARIA 7833 - 22/11/1995 - 70 - VAIVRE-ET-MONTOILLE
38.11 – Collection of non hazardous waste
While transferring smoke residue from the incineration of household waste to a silo in a transfer area of a special industrial waste stabilisation/solidification platform, a tank truck accidentally released four tonnes of ash containing lead, zinc and chromium. The steam-laden emission was spilt on the ground around the platform. Tests were carried out and samples taken. None of the homes were effected.

ARIA 12062 - 02/12/1997 - 33 - BASSENS
38.22 – Treatment and elimination of hazardous waste
In a waste treatment centre, 10 m³ of acid chloride delivered in a vacuum stainless steel tank was transferred to a 22 m³ tank truck. The operation was carried out to dilute the acid before incineration and no other container was available. Right from the start of transfer, an exothermic reaction occurred in the vacuum tank. The delivery truck was isolated but 3 m³ of liquid was released through the vacuum tank's vent and bursting disc. The resulting HCl cloud was dispersed by the wind but a stringent odour was observed in the neighbourhood. The emergency services that were informed 30 min after the start of the accident monitored the situation for five hours. Four employees were poisoned.

ARIA 12164 - 23/12/1997 - 38 - SAINT-QUENTIN-FALLAVIER
49.41 – Road transport of freight
23 m³ of caustic soda leaked from a tank truck and spread to the platform and shoulder. The product as well as 120 m³ of polluted soil was recovered. Road traffic was diverted and the accident area was covered with sand. The material comprising the tank truck (aluminium) was incompatible with the transported product.

ARIA 15096 - 17/03/1999 - 50 - GUILBERVILLE
49.41 – Road transfer of freight
An exothermic reaction occurred in one of the compartments of a tank truck transporting liquid waste (3,000 litre waste nitric acid bath containing 150 g/l of tin and lead, 200 l of ammonia water containing ammonium chloride and 150 g/l of copper) in a parking area. The tank pressure increased causing a vent to open and the liquid to project outside and spread all over the parking area. The driver parked the vehicle aside and exposed the compartment in question to open air. Fire-fighters and a CMIC unit specialised in chemical emergencies monitored the vehicle for several hours. The liquid phases were separated, neutralised and transferred to another tank. The operation lasted for 28 hours. Incompatible products were mixed due to an identification error. The principle of general acceptance renewed every year for a product type has been called to question (routine).

ARIA 20095 - 09/12/2000 - 02 - CHAUNY

20.14 - Manufacture of other basic organic chemicals

In a tank truck loading area of a chemical plant, 5,700 l of 55% waste sulphuric acid leaked while a 42 m³ tank truck was being filled in a pitched retention area. The operation was stopped and the alert sounded. The internal contingency plan was triggered for 2 hours and 30 minutes. A rescue team diluted the acid with water and channelled the corrosive effluent to an 80 m³ floating retention tank where it was subsequently neutralised with sodium hydroxide and sodium bicarbonate. The content of the tank truck was collected in the retention tank. The accident occurred due to the corrosion of the steel tank without coating as H_2SO_4 at 55% is far more corrosive to steel than at higher concentrations. The acid remaining at the bottom of the tank after an incomplete draining operation may have been the cause of the corrosion. The tank truck supplier carried out an additional technical expertise. The operator drafted a new guideline on ordering empty tank trucks from suppliers requesting them to specify in the order slip the quality of the waste acid to be loaded. The use of tank trucks with an internal coating was preferred for such type of transport.

ARIA 29942 - 01/06/2005 - 27 - EVREUX

21.20 – Manufacture of pharmaceutical preparations

Methyl methacrylate vapours leaked when a tank truck was being filled with liquid waste (methanol, ethanol, isopropyl alcohol, acetone, acetonitrile and water) at a pharmaceutical site. A third party, duly commissioned by the operator, transferred the waste stored in barrels using a vacuum pump at 9.20 am. The air in the tank was expelled to draw the waste via a hose but the emitted vapours were collected around 9.35 am by an air-conditioning device in the building near the transfer area.

The transfer operation was stopped at around 10.00 am and the building evacuated. The driver of the private company informed the operator that the methyl methacrylate emissions surely originated from its transit on 31/05 during waste transfer in another industrial site. On the previous day, the tank was only rinsed with water. The analysis carried out by several laboratories confirmed the presence of methyl methacrylate in the waste samples from the tank truck (ratio > 60 between the barrels and truck). The cleaning operation was inadequate and not carried out in an authorised facility. Acute poisoning with methyl methacrylate in concentrations greater than 2,000 ppm could result in neurological disorders along with symptoms like headache observed in the employees. Out of nine people poisoned, eight were hospitalised (four were discharged the same evening and the remaining four on 02/06). One person received medical attention onsite. Two people were on medical leave for 10 and 20 days.

A visit by inspection authorities revealed that five provisions were not respected: accident not declared by the operator, clean-up certificate not produced before transfer of waste as provided for by the safety protocol between the industrialist and the service provider, compliance with safety protocol and state of cleanliness of tank before authorising transfer not verified by the industrialist, technicians not trained in the application of safety protocol and ensuring compliance, safety protocol not drafted in form of an operating procedure. The inspection authorities took note of these facts. The prefect was advised to issue a formal notice demanding compliance with the recommendations of the prefectoral order.

ARIA 32540 - 17/11/2006 - 38 - LE PONT-DE-CLAIX

38.22 - Treatment and elimination of hazardous waste

A technician detected a leak on opening a transfer valve while transferring 2.58 tonnes of chloroprene from a tank truck to a waste treatment site. He reduced the pressure of the tank truck to shut the valve on the mobile tank. 1,200 tonnes of chloroprene spilt onto the drains and the retention area. After having stopped the leak and sounded the safety alert in the facility, the operating team alerted the watch room and the team on standby duty. The use of absorbent products helped curtail the evaporation of the liquid. The watch room failed to register complaints of odour from the neighbouring sites. However, the fire-fighters and a team from the gas department arrived onsite to look for the gas leak. The comparison of the two events led to the establishment of an emergency unit by the staff in compliance with procedures. The transfer of chloroprene was carried out under nitrogen pressure using a rising main due to the regulatory obligation of transporting this chemical in a tank truck that is filled and emptied from the top. Seven tank trucks (i.e. 117.8 tonnes of chloroprene) were already emptied without any major problem using the same procedure specifically drawn up for this tank. After analysing the incident, the leak was found at the joint between the tank truck and transfer pipe. The air-tightness of all pipes, transfer components and tank truck was tested the following day at around 10.00. The satisfactory results obtained authorised the transfer operation that ended at 3.20 pm. Since there were problems in obtaining total air-tightness due to the joints used and space available in the tank truck caisson, the tanks were modified and the quick-fitting unions were replaced by flat faced flange unions used for transfer operations under pressure.

ARIA 32574 - 29/12/2005 - GERMANY - STUTTGART

38.22 - Treatment and elimination of hazardous waste

During the vacuum transfer of liquid wastes from steel drums, hydrogen sulphide (H2S) leaked through the vent of the receiving tank in a hazardous waste treatment plant. Since the hazardous waste could not be treated onsite, they were received in drums, mixed in a tank and transported to another site. A forklift truck operator was found dead in the vicinity and five other people poisoned by H2S were hospitalised. The fire-fighters upon arrival were unable to detect the significant concentration of H2S and left the premises. The police ordered the contents of the suction pipe to be emptied into the tank. The vacuum pump was restarted and the H2S that was released again caused the truck driver to faint. Consequently, the police ordered the operations to stop and the fire-fighters and a doctor on emergency duty were called on site. The total number of casualties included one death and six cases of poisoning requiring hospitalisation (2 employees, 2 members of the emergency department and 2 agents from another company).The emission of H2S triggered a chemical reaction between the two liquid waste products: an organosulphur compound and an organic acid.

This accident revealed an organisational problem: identification, evaluation and documentation on handling containers carrying hazardous products were not adapted, the operating modes for the vacuum transfer of waste from drums into tanks do not specify the order of transfer, there was no safety system to detect gas produced due to a secondary chemical reaction and released from the tank vent. A legal investigation was carried out.The vacuum mixing of hazardous substances in tanks was stopped, and the drums were treated on another site. The administrative authorities put forth preventive measures: identify hazardous waste on their own or in mixtures, define safety criteria to plan out their treatment (pH, etc.), ensure compliance of product storage procedures with safety criteria, specify transfer order for mixtures according to the properties of its hazardous constituents, ensure that the tank vent is connected to a gas treatment unit, restrict access to vacuum transfer zone.

ARIA 34236 - 13/02/2008 - 62 - COURRIERES

38.22 - Treatment and elimination of hazardous waste

In a waste treatment plant, an explosion that occurred around 1.30 pm destroyed a 5-tonne tank truck containing waste water with low concentrations of sodium coming from a chemical plant. Six people were reported injured including one person who sustained severe injuries. Pieces of the truck were projected as far as 250 m from the site of the accident. The operator took charge of ground clean-up operations.

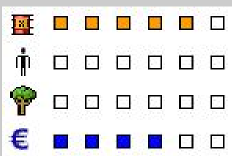
The ensuing investigation revealed that the carrier had violated regulations on transportation of hazardous substances: defects observed during the previous technical inspection of the vehicle, engine oil leak, etc. Several assumptions were made to explain the reasons behind the explosion: defective vehicle, (oil leak), possible overpressure in the tank (no hydraulic test certificate), combination of some molecules contained in the various waste products transported before the accident (no clean-up certificate before the last loading operation), etc.

Domino effects

③ Ignition of an ethylene leak on a pipeline

ARIA 35672 - 17/03/2008 - GERMANY - KÖLN

20.16 – Manufacture of basic plastics



During maintenance operations, there was a leak at the tie-in of an ethylene pipeline connecting several plants in the region and the one connecting a chemical plant manufacturing basic plastics. The valves were closed but the ethylene that stopped leaking from the pipe section ignited. After some time, the heat emitted caused the fire to spread and destroy a by-pass valve leaving 11 km of the pipeline (distance until the next isolating valve) non isolated.

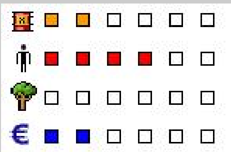
Ethylene contained in this 11 km section of the pipeline was at 80 atmospheres. A massive 30 m high flame was observed. The intense heat flow effected an aluminium tank containing acrylonitrile that was 10 m away. Even though the container was protected by a concrete wall, the acrylonitrile boiled and evaporated. Given the temperature, the container itself was “burning” and risked collapse. The fire-fighting operations became complicated but the blaze was brought under control in the end. However, half of the container was burnt. Material damage was significant but no casualties were reported.

Further to this accident, two expertises put forward several recommendations on improving the safety of pipeline tie-ins, as well as on the minimum distance to be maintained between inflammable gas pipelines and tanks containing inflammable liquids. The local authorities implemented an inspection schedule for transport pipelines of similar configuration implanted near SEVESO sites. The possible application of these recommendations may lead to new inspections, updating of safety reports and adaptations to meet new requirements.

④ Ignition of a hydrogen leak on a pipeline

ARIA 35860 - 12/10/2007 – NETHERLANDS - BINNENMAAS

49.50 – Pipeline transport



A fire broke out in a pipeline passageway bringing together several underground pipes carrying hazardous products such as hydrogen, kerosene, ethylene oxide, etc. The blaze was brought under control in a few minutes given the size of the leakage. The incident had no serious consequences but was nevertheless considered serious due to the presence of the other pipelines in the passageway including some carrying toxic gases.

According to the inspection department in question, hydrogen (H_2) in an underground pipeline was ignited by welding operations underway in the vicinity. A differential subsidence of the ground with a local deformation of the pipeline at the cathodic protection device was believed to the source of the H_2 leak. The sandy nature of the ground was conducive to the subsidence due to the presence of heavy equipment on the surface (drain pump, construction site vehicles, etc.) used during excavation operations carried out for laying a new kerosene pipeline. Even though the transportation of dangerous substances though this passageway is considered to be managed safely, some shortcomings were nevertheless identified. Calculations had to be made to identify the maximum acceptable load above such pipe networks and a more active supervision of pipelines was recommended.

Domino effects

The two incidents of ethylene and hydrogen leak illustrate the dangers involved in transporting inflammable material through pipelines. Several accidents also involve toxic material, combustive fuel, environmentally hazardous substances etc. The ARIA database has recorded around ten such incidents with an impact depending on the fluid transported, its physico-chemical properties, the flow rate and pressure in question and its toxic or polluting effects.

In the event of a leak not igniting immediately when transporting inflammable material, the hazardous liquid or gas may spread to a wider area (ARIA 2257, 14689, 24548, 5371, etc.), through preferred paths (gutters, sewers, cracked grounds, etc.) before igniting or exploding upon contact with a hot point like the passage of a vehicle (ARIA 5817, 126, 3325). The wide spread dispersion of the inflammable material in liquid or gaseous form is a factor that is critical in determining the intensity of the effects especially when ignited later in time. Such accidents can be devastating and result in several victims (ARIA 27681). This point is crucial in defining the safety parameters relating to the emergency plans. Heat radiation can also ignite combustible mattered stored in the vicinity and melt equipment like in the case of the first accident presented (ARIA 27723, 30005, etc.).

The shock wave or blast effect of an explosion, as well as projections of fragments impact nearby installations (ARIA 7128, 29864, 27516, etc.) but can also have a ripple effect far away from the leak site (ARIA 3325, 11649, 19380 ,etc.), specially when the inflammable cloud explodes upon contact with a hot point located several dozen or even hundred metres away from (ARIA 7128, 10173, …) the leak site. Several cases of BLEVE involving toxic or inflammable liquefied gas containers result from pipeline fires (ARIA 6756, 7128, etc.).

Underground pipelines or "pipelines in drains" can be sources of severe pollution (ARIA 23839, 32818) including some rather insidious cases (weak flow rate over a long duration, etc.). Merging of pipes (pipe passages, racks, etc.) deserve special care due to their proximity with several other pipes transporting hazardous substances (ARIA 34176, 2nd accident presented).

The transportation of toxic material such as ammonia (ARIA 5371, etc.) or chlorine (ARIA 29864) also create a public hazard in the event of a leak as well as put at risk the safety of technicians likely to be incapable of safely continuing to operate or stop their facilities (risk of indirect ripple effects).

Corrosive substances are dangerous to a lesser extent but may spread to other more dangerous pipes in the vicinity (inflammable gas or liquid, toxic material, etc.). Water pipes especially with a wide diameter and high pressure (ARIA 16863, 34945, etc.) can cause significant damage by ripping or wetting the soil or even weakening the foundations.

The layout, indication and precise information on the exact location of the pipeline on updated maps, as well as inspection of surface markers of underground pipes are essential elements deserving special care especially in urban, peri-urban, agricultural or natural environments: ARIA 27723, 32818, etc.

Firstly pipes must be equipped with adequate mechanical, chemical and electric protection as they are exposed to several kinds of stress such as natural (landslides, lightning, floods, etc.), mechanical (agricultural equipment, construction sites in the vicinity, etc.), chemical and electro-chemical corrosion (ARIA 12507, 27681, 2257, 35286), etc.

The regular monitoring of pipes while taking into account related units and equipment (compression station, tracing, cathodic protection, connections, manifold, valves, etc.), timely surveillance of seasonal activity (agriculture) or construction (road works, etc.) carried out in the vicinity, as well as regular inspections and tests come next: ARIA 29864, etc.

The accidents whose references are not underlined may be consulted at:
www.aria.developpement-durable.gouv.fr

ARIA 7128 - 19/11/1984 - MEXICO - SAN JUAN IXHUATEPEC

35.22 – Supply of combustible gases through pipes

During the filling phase of an LPG storage area (mixture of 80% butane - 20% propane) comprising 2 spherical tanks of 2,400 m³, 4 of 1,600 m³ and 48 cylindrical tanks (5,000 m³), a pipeline at 8 to 4 bar ruptured. A 150 X 200 X 2 m was formed and ignited after 5 to 10 min at a flare that 120 - 150 m away from the leak site. The VCE caused the BLEVE of the two small spherical tanks after 5 minutes. A fire ball with a diameter of 600 m was formed at the ground level. The zone was destroyed and the populated decimated within a radius of 300 m. Successive explosions occurred until 11.00 am. The fragments of the spherical tanks were projected as far as 600 m as well as 12 fiery rocket shaped fragments (20 tonnes) of horizontally placed cylindrical tanks were projected at a distance of 1m to 1,200 m. More than 500 people died, 7,000 injured and 39,000 evacuated and 4,000 rescue workers were involved in the operations.

ARIA 22249 - 23/12/1987 - IRELAND - COBH

20.14 – Manufacture of other basic organic chemicals

In the ammonia manufacturing unit of a petrochemical plant, a 24" pipeline carrying synthesis gases (43% hydrogen, 14% nitrogen, 12% carbon dioxide and 29% water) ruptured causing the resulting hydrogen cloud (60 kg) to explode. Even though the explosion was heard as far as 2.5 km from the site, the damage caused outside was limited (shattered glass panes, damaged roof). Under the effect of low pressure, an 8 m pipe that was further down rotated by 380° while another 12 m pipe that was further u p rotated by 90° damaging a nearby rack and destroying the vent header of a desulphurisation unit of the refinery from where 600 kg of methane leaked and ignited. Hydrogen from the pipe further up ignited as well forming a 70 m long fiery stream. The alert was sounded and the units secured one after the other. The blaze was put out 5 min later by cutting off gas supply to the plant. Due to this emergency shutdown, ammonia was released into the atmosphere without any reported impact on the population or environment. The material damage on account of the accident was estimated at 0.65 M euros. The pipeline ruptured due to the fatigue induced by thermal cycles. The rupture zone of the pipe connecting a converter to the CO2 absorber of the ammonia unit was near the water injection point that cooled the synthesis gas from 230℃ to 179℃ under 28 bar . The examination of the zone revealed several fatigue cracks on the internal wall of the pipe over a distance of 3 m from the water injection point. Moreover, the water injection nozzle that was probably distorted before the accident modified the direction of the stream but there was no proof to ascertain it as one of the causes of the accident. Lastly, several leaks on account of fatigue were identified on the pipeline over the past two years but were incorrectly diagnosed. The operator believed corrosion due to stress to be the cause. As part of the accident feedback, the facility was modified. The water injection system was replaced with a reboiler system. A general inspection was carried out in the facility with a view to identify similar phenomena. A preventive maintenance plan was implemented.

ARIA 2257 - 08/04/1990 - SEINE MARITIME (76) - PETIT-COURONNE

23.2Z – Manufacture of refined petroleum products

Since at least 1985 there had been leak on a corroded underground pipe conveying unleaded premium gasoline between a storage tank and a petroleum pier. This leak polluted underground water and eventually a DWS (drinking water supply) reservoir had to be abandoned. Gaseous fumes, however, propagated via the cities technical ducts and eventually caused a home to explode 2 km away, most certainly ignited when the hot-water heater tripped on. Twenty days later, a hole measuring just a few square millimetres was found on the corroded piping. More than 15,000 m³ of hydrocarbons had been lost and more than 13,000 m³ had been pumped into the water table. The operator compensated the homeowners by purchasing their home, and paid compensation to the water distributor and local community. The total cost of the work involved exceeded 50 MF.

ARIA 3325 - 30/05/1991 - 13 - BERRE-L'ETANG

20.14 - Manufacture of other basic organic chemicals

A leak occurred on a 10-inch ethylene tube at 45 bar following an electrochemical corrosion of an above ground section and an underground section protected by a protective sheath. It took 20 min to shut the isolation valves (2 km). Despite the safety perimeter set up, a vehicle from an outside company in the vicinity stalled, ignited the smoke upon re-starting and lit a 15 m flare turned towards a 6 m high rack supporting 10 pipes. A second 6-inch ethylene pipeline ruptured and caught fire. A section of the latter fell near the first pipeline that exploded. The fire spread to a warehouse storing 22 m³ of solvents in barrels and 1,000 tonnes of synthetic rubber 20 m away. The quantity of ethylene involved in the accident was assessed to be 32 tonnes. Four people sustained injuries including one person who was severely burnt. Production losses stood at 220 MF. In January 2004, due to lack of maintenance of the pipelines in question, the former site manager was given a 10-month suspended sentence and fined 8,000 Euros, a first-line supervisor of the company operating the ethylene pipeline was given a 6-month suspended sentence and fined 1,000 Euros, an engineer of the same company received an 8-month suspended sentence and was fined 3,000 euros. Five other people facing prosecution were discharged.

ARIA 16863 - 07/12/1999 - 38 - GRENOBLE

36.00 – Collection, treatment and supply of water

A district (200 x 400 m) of the city of Grenoble was flooded with 20,000 m³ water following the rupture of a big pipeline with a diameter of 500 mm. It was hard to determine the location of the leak that was stopped only after 2 hours and 30 minutes due to the high flow rate. The flood caused short-circuits and several start of fires in shops that were quickly extinguished by fire-fighters. Gas and electricity companies were also on site. About a hundred customers from a restaurant were evacuated. The district was completely dried only the following day at around 9.00 pm.

ARIA 14689 - 22/01/1997 - GERMANY - WASUNGEN

35.22 - Supply of combustible gases through pipes

An explosion occurred and was followed by fire in a liquefied combustible gas storage and supply facility. The pump room, electric control room and a part of the regeneration workshop were destroyed. One employee sustained injuries and another one was in a state of shock. Material damage was assessed at 350,000 DM. After investigations the gas pipelines and other underground protective electrical sheaths were not found to be airtight due to the presence of rust. Consequently, the gas infiltrated into the ground. Given the weather conditions (soil frozen at that period), the gas could not diffuse into the air and thus travelled through the leaking pipes below the building to reach drainage areas not connected to the sewage network. An explosive mixture was gradually formed and spread to the surrounding areas comprising rest rooms and wash rooms where even lighting a cigarette could cause the cloud to explode. Equipment and related devices (hoses in liquid or gas phase, loading arm, etc.) were replaced in the product transfer area with tanker trucks. A gas detection device controlled by an automatic emergency shutdown mechanism was also installed.

ARIA 19380 - 06/12/2000 – UNITED STATES OF AMERICA - JAL

49.50 – Pipeline transport

A pipeline with a diameter of 40 cm located 90 cm below the ground and transporting natural gas exploded in a gas conditioning plant. Two tanks situated below the pipeline, one containing methanol and the other glycol ignited in turn. The reason behind the explosion is not known. The explosion created an over 7 m X 6 m X 3 m crater. The fire was confined to the crater, put out by with mud and brought under control in 2 hours. The section on the pipeline was isolated both upstream and downstream. The plant was no longer supplied and had to be temporarily shut down. The section in question was repaired and all sections likely to be impacted by the accident were inspected. A specialised body was called in to investigate the accident.

ARIA 23839 - 12/17/2002 - HAUT RHIN (68) - CHALAMPE

24.1G - Manufacture of other basic organic chemicals

During efforts the previous day to locate the source of a pressure drop on the cyclohexane supply line of an olone production facility, a leak of this substance was discovered at a chemical site. The substance, used in large quantities, is of relatively low toxicity, although it a pollutant and flammable.

Stored in a 10,000 m³ reservoir, the cyclohexane is supplied to the olone and adipontrile (ADN) facilities by a partly common pipeline. Maintained at the proper temperature by a steam system, the cyclohexane is transferred at 20℃ and at 2 to 3 bar through lagge d overhead or buried piping. With an output ratio of 266:1, 2 pipes, 100 and 40 mm, provide a continuous supply to the olone shop and a discontinuous supply to the ADN shop.

The leak occurred from the rupture of the ADN shop's 40 mm pipe due, according to the operator, to the dilation of liquid cyclohexane in the overhead part of the pipe between two blockages of crystallized cyclohexane. A malfunction of the pipe heating device (T < 6.5℃) led to the formation of blockages, with the cyclohexane then reliquifying primarily in the section the most exposed to the outside heating. As the piping was not yet equipped with a device for rapid leak detection, it took 30 hours to determine the cause of the pressure anomaly. The operator initially estimated the leak at just a few m³ of cyclohexane, then between 850 and 1,200 t in the following weeks, the vast majority had migrated into the ground. A few days later, core samples taken at a depth of 13 m (the depth of the water table) showed the presence of a layer of cyclohexane localized near the site of the leak; lowering of the water table by one of the wells of the site's hydraulic security barrier would have limited the spread of the pollution. Analyses of the water table off site showed no trace of cyclohexene above the drinkability threshold. On July 2, 2003, 420 t of cyclohexane were pumped from the water table and 16 t extracted from the ground through venting techniques... In July 2004, 590 t of cyclohexane had been recovered, although cleanup operations had slowed considerably since the first of the year, with the quantities of cyclohexane recovered stabilising around ten tonnes per month. Consequently, a Prefectoral order was issued July 28, 2004 to request that risk analysis be conducted within the scope of a remedial plan.

ARIA 27681 - 30/07/2004 - BELGIUM - GHISLENGHIEN

49.50 - Pipeline transport

The gas pipe connecting Zeebrugge to the Franco-Belgian border exploded violently in an industrial zone. Around 8.30 am, a leak was detected by the hissing sound made by the escaping, still odourless at that stage. The emergency services arrived for the rescue operations in the area located near a construction site of an abrasive tool manufacturing unit comprising around thirty workers. The gas pipe was located 1.10 m below the ground (diam: 1 m; P= 80 bar). At 9.00 am, a violent explosion was felt several kilometres away along with the formation of a massive fire ball (200 m high and 500 m in diameter). The fire spread to a neighbouring petrol station and construction site and destroyed them. The gas pipe was isolated. As of 8 September, the human casualty toll was very high: 24 people died (5 fire-fighters, 1 policeman and employees of the neighbouring companies), 50 people sustained serious injuries (mostly burns) and were hospitalised in Belgium and in the north of France and 79 people sustained light injuries. The most serious state of emergency was declared and a federal crisis unit was set up. Residents were asked to stay indoors and the E429, A8 motorways as well as the No. 7 national highway were closed unit late afternoon. The country deployed significant human and material resources (5 helicopters, army) with backup from France (65 rescue workers, 13 ambulances, helicopters, and an advanced medical unit), Germany, Luxembourg and the Netherlands. Significant and wide spread material damage was reported. According to witnesses these include an approximately 10 m diameter and 5 m deep crater, several hundred m of burnt area, cars burnt to a cinder as far as 500 m, debris scattered up to 6 km. A 6 tonne (?) section of the pipeline was recovered at 150 m. According to the press, suspicious marks (depth: 10 mm) were observed on the recovered section that supports the operators theory of the gas pipe already damaged by a public works vehicle. The operator also added that a change in the operating mode of the pipeline along with the damage caused led to the leak. The pipeline resumed operation on 10.09.04. The adjacent pipeline slightly damaged by the accident resumed functioning on 09.08.04. The final human casualty figures stood at 24 deaths and 132 injured. On the basis of the legal and expert report that estimated that the operation carried out a few months back had damaged the pipeline whose location moreover had not been clearly indicated to the parties involved in the site, the Tournai Public Prosecution confirmed the aforementioned theory and indicted eight natural persons and seven legal persons including the network managing company.

ARIA 32818 - 01/10/2004 – NETHERLANDS - STEIN

20.14 - Manufacture of other basic organic chemicals

A leak detected late on a pipeline (10'', 2 bar) serving a port petrochemical site along the Juliana canal was the caused 3 000 m³ (2500 tonnes) of methyl tertiary butyl ether (MTBE) to be released thus polluting soil and underground water. The MEUSE river flowing nearby was also polluted. The pumping of the river waters meant for human consumption (300 000 persons) had to be stopped.

The leak was detected in October 2004 after a detailed inspection of the pipeline further to problems in the material balance. The leak in all probability lasted long and went undetected during the yearly inspections. The accident occurred due to faulty construction of the pipeline in 1976. The pipeline was built simultaneously from both ends to save time and required the assembly of an S-shaped threaded fastener due to a 70 cm difference in height between the two sections. The welding of the poorly cut component (1.5 cm gap filled in by welding) was apparently not in line with the best practices in the industry and was not inspected. The crack probably grew in size with time and under the effect of ground movements.

Several measures to clean up the site were deployed: excavation of polluted soil, pumping of MTBE, blowing air through the water table and subsequent treatment of the return air, etc. Moreover, a 15 m deep dike separating the Juliana canal was reinforced by a 15 m steel wall (below the ground water level).

In April 2005, 6 months later, the pumping station located 30 km downstream the Meuse river detected a significant hydrocarbon pollution which was later on identified as MTBE. After investigation, it was found that the point of origin of the pollution was at the petrochemical port: an 800 m x 200 m pollution zone of 300 mg/L of MTBE was detected between the accident site and the Meuse river, polluting the river at a rate of 50 to 100 kg / day.

A treatment device covering a wider area was put in place in the beginning of 2006.

ARIA 29864 - 05/21/2005 - ISERE (38) – CHAMPAGNIER

24.1E – Manufacture of other basic inorganic chemicals

An explosion ripped through a pipeline transporting gaseous chlorine between a chemical platform (producer) and an elastomer manufacturing plant (user).The piping, built in 1961 to transport hydrochloric acid (HCl), was being used to convey deoxygenated and dried Cl_2. Measuring 200 mm in diameter and 3,600 m in length, the painted, lagged steel pipe was equipped with an external skin effect heating system and operated at 4 bar (relative) and 30 ℃. Production operations had been stopped the day earlier for a 10-day maintenance shutdown period, and the pressure in the 'chloroduc' had been lowered to 0.25 bar.The explosion occurred 150 m from the delivery point, in an area outside the user's site. The pipe ruptured in 4 locations along a 70 m section and showed traces of internal shock waves. The accident did not claim any victims despite a large amount of pipe debris projected in a 150 m radius. An estimated 475 kg of Cl_2 was released following the explosion. The damage observed (helical rupture, pressure wave...) indicates the explosive character of the accident. The 4 other pipes on the aboveground rack (dia. 100 mm) suffered extensive damage: the 2 nitrogen lines (13 bar, 2 to 3,000 m^3/h) were deformed although were not leaking, and their pressure as reduced to 10 bar; the oxygen line (10 bar), was also damaged and was drained. The last line was no longer in use and was kept under N_2 at atmospheric pressure.Analysis of the accident showed that an H_2/Cl_2 explosion caused the damage. The formation of H_2 (20%) can be explained by the combination of several elements: The accidental introduction of humidity into the piping during a previous maintenance operation may have led to hydration of the ferric chloride present in the pipe's environment. According to the operator, the change in the deposit's crystalline phase due to excessive heating of the pipe (80 to 90 ℃) promoted corrosion in the steel pipe (by the hypochlorous acid) and the formation of H_2. This heating caused a temperature sensor to lose its electrical power supply after a cable on the user's site was broken when a slab protecting the structure was poorly handled, just 3 days earlier. In fact, the proportion of hydrogen (20%) released in the gaseous chloride contained in the pipe, which was capped at each end and kept at low pressure (0.25 bar), formed an explosive mixture requiring very little initiation energy to ignite (in the order of a dozen microjoules or so).The operator cleaned the inside of the structure (2.5 to 3 t of mineral and organic residues were extracted), and had planned to install temperature sensors every 500 m with upper and low safety devices, refurbish and secure the electric (heating) tracing, and perform regular endoscopic inspections...

ARIA 34176 - 20/10/2007 - UNITED STATES OF AMERICA - PORT ARTHUR

20 – Chemical industry

A pipeline carrying ethylene ruptured, exploded and caught fire at around 2.00 am in a chemical plant. The fire spread to three other pipelines including one carrying butylene. Black smoke was emitted in the air, road traffic stopped out of precaution and residents facing the direction of the wind were advised to stay indoors. The fire was extinguished around 5.00 pm and road traffic was resumed. No casualties were reported.

ARIA 35286 – 10/09/2008 – PONT DE CLAIX

49.50 – Pipeline transport

Around 11.30 am, the railway department reported a hydrogen chloride gas leak from a pipeline (MOP 8 bars, NPS 350) connecting two chemical plants due to the emission of fumarole. The surveillance and contingency plan relating to the structure was triggered. The pipeline was depressurised and subsequently drained by the employees.

The leak was caused due to localised external corrosion below the bridge over a stream. During repair operations, paint was directly applied to an iron oxide build-up without polishing the surface. Successive floods and the humidity below the bridge contributed to the corrosion. Water seeped in between the paint and pipe causing deposit corrosion. A specialised company temporarily fitted a watertight collar and a supporting prop onto the structure. The accredited inspection department of the company using the pipeline carried out an inspection on the 9 and 10 of October to ensure the absence of any area conducive to deposit corrosion (humidity, presence of water, retouching). The inspection led to the detection of a high-risk area, more specifically a pipeline passage on the same stream at about 50 m upstream to the previous zone showing corrosion. No additional faults were detected after further checks. The replacement of the pipeline section (20m) was planned during the next shutdown. Following the incident, the operator drafted a press release that was posted online on the company website.

Explosions involving water and molten metal


Source exploitant

⑤ *Explosion in a cast iron foundry*

ARIA 31881 - 15/05/2006 - 08 - VIVIER-AU-COURT

24.51 - Cast iron foundry

In a cast iron foundry that alternates the use of two cupola furnaces every other day, an explosion occurred at 6.30 pm during furnace unloading (carried out via hatches placed underneath the furnace) of meltdown products into a tub. Coke, cast iron and slag were all strewn throughout the building and 30 m² of roof were destroyed. Emergency services were notified and all company personnel had to be evacuated. Positioned 10 m from the cupola furnace and equipped with a powerful hose to spray these products with water should a fire break out, an employee suffered burns to the face and arms and required 4 days of hospitalisation; a second employee went into shock and received treatment from fire-fighters at the scene. According to the operator, a water / molten metal reaction would have caused the accident. The refractory cement enclosing the recovery tub had been set up the very same morning; moreover, the cement drying time was insufficient. The cost of material damage was estimated at 10,000 euros. A number of technical and organisational measures were adopted to limit the risk of a repeat accident: acquisition of 3 new tubs to ensure better alternation of equipment with adequate drying time for the refractory cement (36 hours); storage of tub contents in a zone protected from water; drying, by use of a gas burner, of the tub designated to receive the day's furnace drop; installation of a sound alarm intended to warn personnel during the time of manipulation; updating of the list of individual protective gear (sorted by either specialisation or workstation); layout of an identifiable protection zone; and assignment of a staff member to unload the furnace as well as rewrite the procedure.

Explosions involving water and molten metal

Explosions triggered by contact between water and molten metal are well-known accidents within the metallurgical industry and in some cases lead to significant human and material impacts. The ARIA database has inventoried some fifty events of this type involving molten metals, of both the ferrous and nonferrous variety.

Uncontrolled water / molten metal contact is capable of causing vapour explosions, a strictly physical phenomenon resulting from the vapourisation of water, with projections of liquid metal and a volumetric expansion that creates pressure waves; when exposed to the open air, the water / vapour transformation leads to volume increase by a factor of 1,700.

This contact may also give rise to oxidation-reduction reactions, which in turn generate hydrogen that subsequently burns as it is being produced (ARIA 4525) or that causes a very powerful explosion (ARIA 34800) with effects comparable to exploding several kilogrammes of TNT (resulting in an equivalence of 1 kg of TNT for just several tens of millilitres of water reacting with molten aluminium). In the presence of carbon (steels, cast iron), carbon monoxide emissions with explosive potential may also be released.

A number of phenomena, of both physical and chemical origin, arise at high temperature:

- ✓ Liquid H_2O → vapour H_2O (volumetric expansion due to the change in physical state)
- ✓ Reducing metal + H_2O → oxidised metal + H_2
  then H_2 + ½ O_2 → H_2O (explosion resulting from combustion with the oxygen contained in air)
- ✓ C + H_2O → CO + H_2
  then CO + ½ O_2 → CO_2 (explosion resulting from combustion with the oxygen contained in air)

The circumstances of these explosions are apparent in all production phases: when melting inside a furnace (ARIA 23912, 27316), subsequent to metal casting in ingot moulds or ladles (ARIA 17205, 17548), upon discharging slag (ARIA 8640, 34527), and lastly during the transport of metal ladles (ARIA 23317). The prevention of these kinds of events requires an exhaustive risk analysis of each operating phase.

Organisational and human deficiencies contribute considerably to the occurrence or exacerbation of such events. Dropping a liquid steel ladle following inappropriate handling or stowage and inadequate controls (ARIA 28574), feeding the furnace with a wet load (ARIA 34239, 34513), massive casting of molten copper within a quenching tank (ARIA 3924) all serve to illustrate this recurring hazard. A set of adapted operating procedures and recommendations, in conjunction with the steps of dissemination and compliance among technical staff and contractors, and personnel training in risk management constitute the basic rules applied to limit the occurrence of these anomalies. Observed equipment deficiencies include worn refractory material (ARIA 8044) and/or cooling system leaks on installations (ARIA 4876), and leaky roofs (ARIA 22976); these provide examples, should it be necessary, of the need for a preventive maintenance programme to be properly coordinated (ARIA 26928, 33059) and the benefit of monitoring processes that introduce appropriate measures should anomalies be detected (ARIA 33059).

Exceptional causes, "external" to the facility, might also be the source of these water / metal contacts, as illustrated by the vapour explosion that occurred in Japan following the overturning of a metal railcar by a 15,000 m³ wave of water, which itself was caused by the sudden bursting of a gas-holder (ARIA 104).

In some cases, the human toll is of alarming proportions; 5 employees killed and 5 others injured in a steel foundry (ARIA 29633), 5 dead and 4 seriously hurt at a ferromanganese production plant (ARIA 34276), 1 death and 1 injury in a steel mill (ARIA 3512) are indicative of the severity of this risk. In addition to human casualties from accidents, the physical damage as well as operating losses can be sizeable (ARIA 28574), and the ensuing facility renovation works can disrupt operations and force layoffs for a number of weeks (ARIA 5663).
The introduction of containment cells for operator's protection (ARIA 17552, 29851), mandatory wearing of suitable protective gear by staff (ARIA 17548) and strict limitations on the number of individuals circulating within high-risk zones (ARIA 34513) offer a sample of measures taken to mitigate the consequences of accidents for personnel.

A violent phenomenon with potentially dramatic impacts, a "water / metal explosion" deserves special attention from facility operators. Compliance with the rules of good engineering practice for furnace operations and maintenance, coupled with effective management of all molten metal / cooling water interfaces and proper handling of infiltration/inflow (leaks, spills, etc.) are prerequisites for limiting the occurrence of such accidents. Achieving implementation of the corresponding set of preventive measures among all parties potentially involved in unit operations actually defines the level of risk prevention.

The accidents whose references are not underlined may be consulted at:
www.aria.developpement-durable.gouv.fr

ARIA 104 - 15/01/1989 - JAPAN - SAKAI / OSAKA-FU

24.1 - Steelmaking

As a result of a defective weld performed 15 years prior, cracking led to the sudden bursting of the water tank on a 35,000 m³ gas-holder and the discharge of 15,000 m³ of water and 25,000 m³ of gas containing a 70% concentration of CO. The CO cloud immediately ignited. The sheet of water overturned a railcar full of molten metal ("torpedo car" design) awaiting processing onsite and generated a vapour explosion. The metal projections then caused the fire to spread to 3 other buildings also part of the facility. The blaze was controlled in 3 hours thanks to a fleet of 17 fire-fighting vehicles. One injury was reported.

ARIA 3924 - 09/09/1992 - 33 - MERIGNAC

24.54 - Foundry for other nonferrous metals

Technician mishandling caused an explosion, resulting from the instantaneous vapourisation of quenching water subsequent to a massive casting of molten copper. Both the quenching tank and roof were destroyed. One facility employee was hurt and the furnace had to be turned off.

ARIA 4525 - 10/06/1993 - 38 - JARRIE

24.45 - Metallurgy of other nonferrous metals

During unloading of a furnace used for activating the reaction of zirconium tetrachloride ($ZrCl_4$) on magnesium (Mg), an explosion occurred within a plant material handling zone that manufactures zirconium sponges.

Plant staff present at the time suffered hearing loss without perforation of the eardrum; the resulting material damage was phenomenal: 3,000 m² of plant siding and roofing, made of asbestos cement, were pulverised from the detonation blast; ditch cover gratings were projected 3 to 5 m into the air; the building door was torn off; hinges broken, etc. These damage observations suggest that the explosion represented the equivalent of 1 kg of TNT. The associated costs were estimated at 4.5 million francs.

The hypothesis of liquid magnesium flowing in a ditch that also contained equipment washing water was put forward. The explosion could have resulted from several simultaneous phenomena, including the formation of hydrogen by means of water decomposition, water vapourisation, and grinding of magnesium and its reaction with oxygen from air. An expert appraisal concluded however that only the thermal explosion (water vapourisation) could explain the level of damage recorded: the reactions of magnesium oxidation with water or air were contained; and the magnesium spill in the ditch served to generate hydrogen in a quantity proportional to the spill, with this fuel burning at a rate corresponding to its release at the ditch (given the presence of fire and sparking prior to the explosion).

The measures adopted to reduce the probability of recurrence of such an accident were as follows: creation of a metal retention structure for storing reaction cells after unloading while waiting for them to cool, temperature control by means of a temperature colour indicator before any handling, elimination of all washing channels and ditches in the plant that may contain water.

ARIA 4876 - 02/12/1993 - 78 - PORCHEVILLE

24.32 - Cold rolling of metal strips

At a steel mill, an explosion occurred inside an electric furnace following a water leak in a cooling circuit. The blast from the explosion tore off metal siding and broke a number of windows. Nine slight injuries were recorded along with some furnace equipment damage; 50 fire-fighters were called to the scene.

ARIA 8044 - 17/10/1995 - 55 - STENAY

24.52 - Steel foundry

A 1-tonne capacity electric induction furnace exploded inside a steel foundry without causing any casualties. The production loss was estimated at 400,000 francs per week of plant downtime. Water spraying onto the molten metal subsequent to heavy wear of the refractory material (despite having been inspected just a few hours prior), combined with the perforation of copper cooling tubes due to melting, were responsible for this accident. An independent body was contracted to investigate.

ARIA 17552 - 11/04/2000 - 78 - BONNIERES-SUR-SEINE

24.10 - Steelmaking

In an electric steel mill, once the furnace (capacity: 70 tonnes per casting) had been emptied into a ladle, an employee was called in to plug the drain hole, which represented the only operation still not automated. As the employee entered the "Dog House" (name given to the concrete enclosure surrounding the furnace), an explosion of vapourised water in contact with the molten steel occurred, killing him on the spot. The furnace was damaged: the cover became misaligned, and the vaulted chamber was projected several metres. A material defect (water leak on the cooling circuit) was the suspected origin. The premature entrance of the employee into the protective enclosure, even though the furnace had not returned to the normal position, would have been the fateful cause of the employee's death. A judicial investigation was conducted.

ARIA 26928 - 14/04/2004 - 87 - LE PALAIS-SUR-VIENNE

24.10 - Steelmaking

Around 7:30 pm, 5 or 6 vapour explosions in less than 60 seconds damaged the furnace (operating at 1,550℃) of a plant engaged in reprocessing industr ial waste by means of pyrometallurgy techniques. The accident was caused by sudden contact between cooling water and molten metal and slag after perforation of the furnace sidewall due to refractory material wear; some 2 to 3 tonnes of molten metal and 35 tonnes of slag spread within the building. Three employees had to be hospitalised for hearing tests; one of them positioned 20 m from the point of explosion was diagnosed with a lesion on an eardrum, yet the condition was not found to be irreversible. Material damage was also observed: the 17-mm thick window pane on the facility's control room located 11 m from the explosion was destroyed, walls shaken without any collapse, broken glass and small-scale damage within a 40-m radius, melting of a portion of the collectors, damaged pipes, etc. The inoperable installations were secured. The inspectorate for hazardous facilities performed an investigation, and the expert appraisal evaluated the source term of the explosion to be 200 g of TNT, which corresponds to the abrupt pressure expansion from 55 to 1 bar of slightly more than 1 l of water at its maximum superheat temperature (270℃). Following piercing o f the furnace (an opening 66 cm long by 15 cm high above the casting zone), the first explosion would have been generated from contact between a small quantity of water and molten material near the casting zone. The second blast erupted once this material arrived into the cooling water collector pipe from the furnace casing (producing a thin liquid film inside the collector). The third explosion, which occurred 10 seconds after the first and according to witnesses was the most violent of the three, resulted from trapped water that had accumulated locally due to molten material flowing into pipe discharge zones. The other explosions were of much smaller magnitude and attributed to random water / melted material contact. The refractory materials refurbished in January 2004 were inspected; early abrasion subsequent to micro-fracturing following an assembly defect was cited for having prevented the creation of a sufficient dilatation space. Several measurements were taken: backup temperature measurements and their interpretation in the aim of preventing furnace perforation, confinement of potential water accumulation zones to avoid contact with molten material, issuance of guidelines laying out the set of operator actions and means for ensuring operator protection during accidental situations.

ARIA 28574 - 18/11/2004 - 57 - GANDRANGE

24.10 - Steelmaking

A 160-tonne ladle of liquid steel pivoted and then became unhinged around 3:00 am inside a steel mill; the accident occurred during ladle lifting by the rail-mounted bridge crane that connects the refining station with the continuous casting shop. The explosion was triggered when the molten metal made contact with the wet concrete shop floor outside the recovery ditch; fire-fighters extinguished the molten steel. An employee burned by the steel heat rays radiating at 1,500℃ had to be hospitalised, and 6 ot her employees are slightly injuried by explosion. Both the building siding and sheet metal protections on the adjacent workshop were blown out. The inappropriate positioning of one of the two hooks on the metal ladle and inadequate control (as specified in a recommendation) by the staff member assigned responsibility for verifying load fastening were the causes of this accident. The material damage was assessed at 500,000 euros, while production losses amounted to 700,000 euros.

ARIA 29851 - 16/05/2005 - 59 - GRANDE-SYNTHE

24.10 - Steelmaking

In a "*Seveso*"-classified hazardous installation, two explosions and the release of reddish smoke took place around 11:00 am during the casting of molten iron using a 450-tonne drum ladle wagon in a ditch at ground level. The technician stopped the spill. This casting step had been approved following detection of a flaw right at the wagon spout, which blocked normal transfer of the cast iron into straight ladles. Notified by numerous phone calls, fire-fighters advised onsite personnel on how to seek containment. No one was injured given that the casting control station was protected (bunker style) and a safety perimeter had been permanently marked off around the ditches. Water / molten metal contact was responsible for the accident; the excessively quick casting operation confined humidity from the tailings that composed the ditch bottom and caused the vapour to explode. The casting of residual 250-tonne loads, performed without incident around 12:30 pm, would nonetheless produce another reddish plume.

ARIA 33059 - 08/06/2007 - 78 - PORCHEVILLE

24.10 - Steelmaking

In an electric steel mill at 7:10 pm, the supervising operator of a melting furnace (70-tonne capacity) noticed blue flames from the surveillance camera images, interpreted as a sign of the presence of water in the furnace. He closed the safety hatch in front of the glass pane separating the control booth from the furnace enclosure and proceeded by requesting the evacuation of all personnel in the area. A powerful explosion occurred a few moments later upon contact between water and molten metal.

During the afternoon, a water leak had been observed on two cooling return tubes from the furnace crown; one was changed and in order to remedy the second, it was decided to activate the emergency return circuit. Since the water valve on this backup circuit had not been opened, a cooling system malfunction occurred and caused perforation of a tube and, along with it, water inflow into the furnace. Two employees sustained slight concussions and were taken to hospital; they were both released during the evening. The material damage was significant: collapse of doors on the "dog house" (furnace enclosure), broken crown suspension tie rods, projection inside the building of a portion of the smoke recovery device. The cost of this material damage was estimated at 1.64 million euros, with operational losses totalling 630,000 euros.

During its investigation work, the hazardous installations inspectorate recorded the following: an inadequate organisation of maintenance work specific to water supply pipes feeding the furnace crown (procedures, management of technical personnel, monitoring, etc.), onsite instrumentation unable to efficiently control either furnace crown cooling or water circuit function (no temperature or pressure variation measurement), and the lack of instrumentation on the backup cooling circuit. The operator commissioned an investigation by an independent body in order to elucidate the causes of this accident as well as determine both the technical and organisational measures to adopt for avoiding a repeat accident. The investigation also provided specifications for: backup circuit instrumentation, maintenance organisation overhaul, implementation of a hydrogen detector, and completion of a study on cooling circuit instrumentation to improve efficiency monitoring.

ARIA 34276 - 24/02/2008 - SOUTH AFRICA - CATO RIDGE

24.10 - Steelmaking

An explosion occurred on a Sunday morning in one of the blast furnaces of a ferromanganese production plant, destroying a wall of the facility control room; 5 employees died and 4 were seriously injured. According to the press, a water / molten metal contact could have caused the accident. Authorities then closed the plant to allow for the industrial inspection team to assess the level of installation safety.

ARIA 34513 - 25/04/2008 - 03 - COMMENTRY

24.10 - Steelmaking

An explosion took place around 3:00 am in a 28-tonne electric furnace inside a steel mill. The POI Internal Emergency Response Plan was activated, all fluid feeds were shut down and local fire-fighters were alerted. The molten metal was transferred from the furnace using a ladle. Local rescue crews were not called to the scene as the pressure surge from the blast was confined to the furnace (furnace crown brought down internally). No injuries were reported since personnel were not in the vicinity at the time of the explosion. No layoffs had to be scheduled either.

The leading potential cause of the accident was the same as that responsible for the explosion that occurred in this same facility on February 8, 2008 (see ARIA reference no. 34239), i.e. water / molten metal contact due to the presence of water in significant quantity being introduced via a "big bag" of in-house recycled dust as part of the steelmaking process. These bags were being stored outdoors. It would appear that the loading operator did not comply with the set of internal rules established following the previous accident, which forbade the use of dust bags that would have been exposed for more than one day to the open air. Management reinforced these procedures and tightened controls on all charging of materials in the furnace.

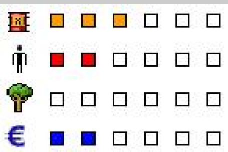
Pipe fittings and joints

DR

⑥ Explosion of hydrogen in a fertilizer plant

ARIA 31821 – 01/06/2006 – UNITED KINGDOM - BILLINGHAM

20.15 – Manufacture of nitrogenous products and fertilizers



Shortly after midnight, a highly flammable gas leaked in an ammonia manufacturing unit of a chemical plant producing nitrogenous fertilizers. The gas, mainly comprising hydrogen, leaked from a valve at a pressure of 220 bar and a temperature of 120℃. It spontaneously ignited forming a fiery stream directed towards the pipeline carrying the gas. Due to the heat, the pressure in the pipeline increased; the top portion of the pipe ruptured releasing the gas that exploded.

The alert was sounded and the police implemented an emergency plan: traffic was stopped in the roads in the vicinity of the plant and resident were asked to stay indoors.

The rest of the gas burnt at the rupture point for 2 hours. The leak was plugged and the fire brought under control at 2.45 am. The site was secured. Human casualties included 2 employees who suffered mild concussions and sustained cuts. They were treated onsite. The plant operations were stopped during the enquiry.

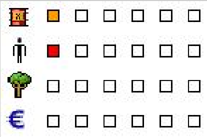
The accident occurred due to a gas leak at the joint of a valve (in open position and at maximum flow). There was no leak-proof joint between the two metal parts in contact. The internal metal surface of the valve was not compliant with the specifications in terms of quality. The valve, replaced in 2002, was not considered to be an element critical to the safety even though the process was classified in the high-risk category. Only price was taken into consideration while selecting the maintenance supplier. There was no exchange of information between the operator and the subcontractor during the operation and no acceptance of work was done (especially inspection of the valve bolting).

The operator revised procedures, optimised management of maintenance and subcontractors (qualification, information, follow-up, etc.). The emergency operation conditions were also reviewed (appropriate number of trained staff even during low activity periods).

⑦ Chlorine leak during transfer

ARIA 34397 – 14/02/2008 - 04 - CHATEAU-ARNOUX-SAINT-AUBAN

20.14 – Manufacture of other basic inorganic chemicals



In a chemical plant, 11 kg of chlorine leaked around 9.30 am while being transferred in liquid phase from a tanker. The leak lasted for 30 seconds and led to the formation of a 50m cloud at the ground level that drifted with its visible part confined to the site premises. The technicians closed the valves by shutting off the supply of compressed air, sounded the alarm, and activated the water curtains.

The technicians who were not equipped with their self-contained breathing apparatus were poisoned by the fumes and taken to the infirmary.

The accident resulted from the rupture of the flange joint of a transfer hose during the tightness test. The joint was deformed because of the use of two 2 mm joints instead of one 4 mm joint. The operator who performed the tightening operation was undergoing training: The tightening operation was not properly carried out with the bolting machine. Lastly, the tightness tests were carried out in a chlorine atmosphere instead of nitrogen.

Since the flanges were not damaged, the transfer from the tanker was smooth during the afternoon.

The operator took several measures after the accident: strict compliance with the safety instruction on wearing a self-contained breathing apparatus, ensuring consistency in issuing permits for various industrial operations, updating technician training on tightening operations, exclusive use of 4 mm joints.

Pipe fittings and joints

The chlorine leak at Château-Arnoux-Saint-Auban once again illustrates the risk related to transfer operations and more generally all transfer operations involving connecting pipes with fittings. This accident occurred due to a combination of errors during the operations (technicians undergoing training without PPE, wrong choice of joint, poor bolting etc.) along with organisational failures such as non-compliance with guidelines and carrying out the tightness test in a chlorine atmosphere.

It is important to properly prepare all transfer operations. Several fittings along the length of a pipe must be avoided. The diameters of all pipes used must be uniform and in line with the diameters of the fixed or mobile storage tanks. Besides accidental mixing of incompatible products, assembly errors may also result in several incidents of leakage. All joints, flanges and hoses must be firmly secured and their suitability verified (ARIA 4982, 6958, 10165, 17740, 23545, 26918, 29885, 32174, 32145, 32817, 32966, and 34397). All bolts must be present and properly screwed in (missing or poorly screwed bolts: ARIA 11441, 12574, 14500, 17740, 34397, poorly screwed or upside down pipe fittings: ARIA 15660, 27207, 31667, etc.). Flanges and buffers must be correctly positioned to avoid joints from sticking out of their grooves (ARIA 14675, 10783, 18920, 17740, 30507, 30486 (not re-assembled), 31667, 32145, etc.).

Lastly, the material and size of joints and hoses must be verified as early as the design stage and their condition regularly checked during use. Material incompatible with the transported product can quickly lead to tightness problems (ARIA 4995, 5872, 25477, 29603, 31489, 33311, etc.). Similarly, corrosion, thermal embrittlement or ageing of joints / flanges / nuts considerably accounts for rupture (corrosion and ageing: ARIA 4989, 4323, 454, 5872, 12574, 14675, 21123, 21282, 25477, 25683, 27207, 33311, freeze/freeze thaw embrittlement 10331, 29096 or thermal action of the transported fluid: 24064, 28762 and 32174). This is why preventive maintenance must be carried out on all equipment.

The accidents also underline the importance of organisational aspects, even for phases considered ‘simple’ such as transfer. Training and qualification of technicians even their accreditation to perform a specific function is crucial in carrying out safety operations. The importance of the involvement of supervisory staff, employees and subcontractors understanding guidelines, as well as the crucial role of upkeep of facilities no longer needs to be proved (ARIA 14500, 30486, 34397, 32796, 33311, etc.).

With particular reference to transfers, pressurisation tests must be carried out with an inert fluid (often nitrogen). These tests help detect and resolve all tightness problems beforehand. The absence of such tests is often the reason for accident (ARIA 4982, 17740, 25683, 31337, 32796 and 34397, 31251 test poorly conducted).

Efficient preparation guarantees smooth transfer while any shortcomings in procedures invariably lead to accidents. Once the pipes have been properly installed, an inert fluid must be used for verification. However, while using compressed fluids (ex. N_2), the gas must be allowed to expand before being injected into the circuit failing which the equipment can sustain serious damage due to an abrupt increase in pressure (ARIA 22941).

The accidents whose references are not underlined may be consulted at:

www.aria.developpement-durable.gouv.fr

ARIA 12574 - 19/01/1998 - 01 - SAINT-MAURICE-DE-BEYNOST

22.21 – Manufacture of plastic plates, sheets, tubes and profiles

The French railway staff noticed five litres of methanol leaking from a tanker drawn outside the sender company 48 hours after being filled. The leak occurred at one of the lateral plugs of the tanker's drain pipe that was not correctly secured. The plug was screwed back properly and the tanker sent back to the sender company to be emptied. The accident occurred due to the failure of three cut-off elements assembled in series (poor tightness of the operating spindle at the bottom even though leaded, insufficient tightness/closing of the control valve and poor tightening/degradation of the safety plug joint. The operating modes were checked and the various players involved were briefed on the same, the checks on tankers leaving the company were tightened and customers were made aware on the need to regularly inspect the state of their tanks.

ARIA 14500 - 03/12/1998 - 01 - SAINT-VULBAS

21.10 – Manufacture of basic pharmaceutical products

In a fine chemical plant, a toluene leak in a solvent reception tank (300 litres)connecting a dryer (3 000 litres) caught fire while the facility was being cleaned with toluene. The solvent (whose temperature was close to room temperature) present in the reception tank and pipes (including the liquid seal) leaked from the cover joint and caught fire. The ensuing flash opened the doors of the premises. The internal contingency plan was triggered. A dozen employees who sustained light burns were evacuated. The person who suffered the most injuries (3 days stoppage of work) was closest to the reception tank at the time of the incident. The accident took place during the first production cycle. The drain pump of a tank failed to start following an electrical defect in a terminal board (poorly secured lug). This led to the excessive filling of the tank that gave in to the hydrostatic pressure (cover not airtight). The unit was newly installed and had several faults in the design: reception tank without retention unit and undersized compared to the centrifuge volume which meant that the pump had to be started several times, non-redundant level alarm, plastic making up the tanks and pipes not adapted to the dielectric properties of toluene, tank made of fragile plastic material, poorly secured cover, etc. During a visit, the inspection authorities of classified facilities observed anomalies in the pipe of the installation: Time / operation log book pre-filled by operator until 10.00 am where as the accident took place at 8.00 am, only seven bolts to secure the cover of the reception tank instead of eight, the eighth bolt was replaced with a clamp; only four bolts were mentioned in the original plans. Various measures were taken: some portions of the pipes were changed, dryer's drain cones maintained under pressure and instrumented, explosive atmosphere detection improved of, overflowing during automatic delivery of solvents prevented via the tank storage area, safety mobile valve on the reactor power supply bypassed. The accident is illustrative of organisational errors and design faults.

ARIA 15660 - 29/05/1999 - 03 - COMMENTRY

20.14 – Manufacture of other basic organic chemicals

In a chemical plant, 1 litre of chlorine leaked out of a container in a non-confined canopy depot housing 16 1-tonne tanks (including two being emptied) and a drawdown station in vapour phase. The Cl_2 detector of the depot was triggered and fire fighters wearing self-contained breathing apparatus arrived on site. Two leaks were detected: one at the nozzle flange and the other at the body flange. The tank was cooled, put away in a shaded place and a cover was placed on the nozzles to isolate them. The container was bled and the chlorine was transferred to a production unit 30 min later. The toxic cloud remained confined to the storage area and its immediate vicinity. No effects were observed outside the plant. A technical expertise of the tank revealed that the Cl_2 leak undoubtedly resulted from a stuffing box that might have been loosened by a plant technician. Some valves have a reverse pitch.

ARIA 17740 - 15/05/2000 - 60 - VILLERS-SAINT-SEPULCRE

20.16 – Manufacture of basic plastics

340 kg of butadiene leaked from a 55 m³ reactor in a plant manufacturing ABS resins. Following pre-polymerisation tests (safety systems, reactor pressure test), 25 tonnes of water, emulsifying agent, an initiator and 15 tonnes of liquid butadiene under a pressure of 8 to 10 bar were added to the reactor. . The water temperature was raised to 80 °C.

The pressure inside the reactor normally goes from 10 to 3 bar with the reaction going on. The partial pressure of 3 bar indicates the end of the reaction and the butadiene that did not react is recovered by stripping. The reaction normally last up to 15 hours.

At 3.45 pm, while the polymerisation reaction had been underway for 90 minutes, a butadiene leak occurred in the lower part of the reactor at the blind flange located just after the pneumatic waste valve. The technicians in the control room are alerted of the sudden opening of the valve via an indicator. This was not a major problem for the operator as the circuit was closed by a protective cuff and a blind flange. The technicians tried to close the valve but did not succeed. One of them went to the reactor to manually close the valve but could not reach it due to the foam released from the lower part of the reactor. He smelt the characteristic odour of butadiene. At the same time, the leak activated the gas detector network, one of the gas detectors being situated vertically above to the reactor. Some detectors crossed the upper threshold of the alarm (40% of the LEL). The internal emergency plan was triggered and the operator decided to open the pressure relief valve of the reactor towards the flare circuit located on the reactor's containment dome. The pressure of the latter decreased, stopping the leak in less than 30 min. The flaring lasted for 1 hour and 15 minutes. The detectors returned to their original state one hour after the start of the accident. The measurements made around the site revealed no contamination.

The accident analysis highlighted three concomitant factors: failure of the pneumatic waste valve with leakage at the O-ring of the push button controlling it resulting in a pressurisation and opening of the valve; the defect in the blind flange joint just after the valve; the inappropriate assembly of the blind flange with the wrong number of bolts and insufficient tightening. Moreover, no pressure test had been undergone on the equipment before. Subsequent to this accident, the facility was not re-commissioned. Polybutadiene production was carried out at another site of the group. Ever since, polybutadiene was supplied by road tankers. However, the prefectoral order dated 14/11/2000 subjected the possible re-commissioning of the unit to compliance with certain provisions on risk prevention planning, implementing clear operating guidelines, preventive maintenance of facilities, regular inspection of safety devices, piping network of the facilities and vital safety equipment..

ARIA 25477 - 14/08/2003 - 69 - PIERRE-BENITE

20.14 - Manufacture of other basic organic chemicals

In a chemical plant, 33 % hydrochloric acid solution leaked out of a transfer pipe connecting a production unit to a waste water treatment pit. The fire-fighters on site neutralised the acidic vapours with a deluge gun, two water shield nozzles in the immediate vicinity of the leak and one adjacent to the site. Water curtains in a neighbouring production unit were deployed to protect a nearby motorway. The leak was stopped after an hour and thirty minutes (after isolating the pipe) and had resulted in a loss of 20 m³ of hydrochloric acid, mainly recovered along with the fire water in the site's neutralisation pit. Heavy corrosion was seen at the sides of the pit. The facility was repaired overnight and re-commissioned. According to the operator, the acidic cloud did not interfere with the neighbouring motorway traffic. The accident was due to a rapidly corroding flange joint on the vent supplying hydrochloric acid to the neutralisation pit. The bolting that was rapidly corroded by the acid gave in and led to the leak. The pipeline was made of surface-treated PVC, the joint used was in expanded PTFE with a zinc-plated/bichromate bolting. The operator sought a feedback on adapting the type of joint used in presence of HCl and studied the possible impact of vibrations on the tightening of the joint. Moreover, an instruction to isolate the acid pipe had been put in place.

ARIA 30486 - 16/08/2005 - 02 - CHAUNY

20.14 - Manufacture of other basic organic chemicals

During a transfer operation from a barge in an upper tier SEVESO chemical site, 60 m³ of orthoxylene spilt onto the barge. The spill lasted for 45 minutes and polluted the OISE river. The operator reported the presence of a 300 m long hydrocarbon layer on the water surface. The internal contingency plan of the site was triggered. The inspection of the facilities classified, navigation department, local authorities and health authorities were informed. Air samples were taken to detect any possible formation of an explosive atmosphere. The measured xylene concentration near the river banks was in the order of 200 ppm (LEL 10 000 ppm). Four oil booms were installed downstream to the spill: two installed by the operator near the plant, two by the fire-fighters at 5 and 10 kms. However, they could not recover the products due to dilution and volatile nature of xylene. No death of fish was reported. The residents and especially local farmers were warned. They were advised against using the river water for animals. The infiltration of pollutants from the river bank into the river caused pollution to resurge on the following day at the site of the spill. An oil boom, pumping device, and site cleanup operations will be required to clean the soil polluted by xylene. The accident was caused due to a missing stop on the inspection flange of the transfer pipe: It was the 1st transfer operation after the pipe was de-commissioned for maintenance. While inspecting the pipe with a camera, the stop on the inspection flange has been removed and not re-assembled. This operation was carried out by a subcontractor who had only received verbal instructions from the operator instead of a concise written procedure. This oversight was not detected even during the inspections carried out upon site completion. The inspection authorities made note of the facts. The operator must modify the transfer facilities to detect leaks in transfer pipes and improve the safety management system.

ARIA 32174 - 24/04/2006 - 76 - GONFREVILLE-L'ORCHER

20.15 – Manufacture of nitrogenous products and fertilisers

While re-starting an ammonia production unit in a chemical plant following a technical breakdown that lasted one hour and 30 minutes, a synthesis gas leak (50% hydrogen, methane, nitrogen and 17% ammonia) ignited on a flange (O-ring joint) located just after the synthesis reactor. The operator triggered the emergency shutdown after the unit's alarms were triggered, isolating and depressurising the synthesis cycle. Steam was sprayed on to the leak using mobile fire nozzles to extinguish the fire that was brought under control 55 minutes following its start.

Material damage was estimated at 60 K euro and concerned the thermal insulation of pipes, louvers protecting the reactor against atmospheric action, fire-proof concrete of the reactor frame and the instrumentation cables within a radius of 3 m. The blaze did not damage the reactor that was protected by a deflector. Operating losses stood at 300 k euro.

The tightening torques of the bolt on flange where the leak occurred is responsible for the accident: they were not adapted to the exceptional conditions prevailing during the accident (significant temperature difference between the bolt and the flange resulting from the abrupt temperature variation due to the short technical breakdown.)

The implemented corrective actions involved redefining the tightening torques, improving the tightness of the drip collar on the flanges (defective at the time of the accident), designing a nitrogen injection system in drips collars and installing a steam injection crown to protect the bottom of the synthesis reactor.

ARIA 32796 - 12/02/2007 - 06 - GILETTE

20.14 - Manufacture of other basic organic chemicals

At around 6.00 am, a flash was produced during operations in a chemical plant. The accident took place between two production campaigns. On the 7 and 9 February, the hydrogenation reactor was cleaned, deodorised and dried to eliminate residual waste from the previous production cycle and prepare the reactor for the following one. On 12/02 at 5.00 am, the production supervisor issued specific instruction on a new production cycle to a technician. The technician did not follow them in the right sequence as indicated in the verification instructions before staring production: to save time when pressurising the device at 9 bar of nitrogen, he simultaneously made several adjustments and carried out several checks (opening the manual hydrogen valves of the storage tank, the emergency shutdown valve just in front of the workshops, etc.). The reactor and safety process valves in front of the reactor were protected by a check valve that remained closed. The reactor was pressurised using nitrogen. The operator observed N_2 leaking from a manhole. He decompressed the reactor and removed the fastening bolts from the lid to change the joint. During this operation, he heard a leaking noise at the joint. Believing it to be a H2-leak, he blocked the reactor and triggered the emergency shutdown of the workshop. He was convinced that the reactor was clean and the residual volume in the pipe was low and proceeded to change the joint with assistance from a fellow technician. The two technicians were projected backwards in an explosion that ensued. The internal contingency plan and ETARE plan (emergency plan drafter by the regional fire service) were triggered. Both the technicians sustained burns on their faces and hands and were initially hospitalised in Nice and subsequently transferred to a specialised unit in Toulon. A safety alert was sounded in the workshop. The gendarmerie (French military police) carried out an enquiry to determine the cause of the accident. The news was published in the press. The operator decided to shut down the site for 48 hours. The commissioned expert explained that the explosion occurred as a small quantity of H2 ignited upon contact with the catalyst in presence of oxygen coming from the manhole. He also noted that the tightness of the reactor was checked and the pipe pressurised at the same time without following the guidelines, no tightness test was planned on the valves of the H2 pipe and that there was not specific instruction on opening the manhole during normal or degraded mode as well as for changing the joint. The current Le montage H2 sampling and introduction assembly increases the risk of leak on valves before the reactor and in the presence of a catalyst in the reactor. The drying conditions may have contributed to have increased the pyrophoric nature of the catalyst. Changes have been planned in the hydrogenation equipment (installing pressure sensors, flame guards on regulator vents, etc.) and procedures (risk analysis, verification of H2 pipes, de-commissioning the H2 pipe before opening the manhole.

ARIA 32817 - 29/11/2006 - 77 - GRANDPUITS-BAILLY-CARROIS

20.15 - Manufacture of nitrogenous products and fertilizers

In a chemical plant, there was an explosion and a leak that ignited at the flange of a relief valve on the turbocompressor of an ammonia (NH3) manufacturing workshop being re-started. The hydrogen detectors and the fire alarm alerted the control room and sounded the safety alert in the plant. The rescue team gained control of the situation in a few minutes. The internal emergency plan was not triggered.

No victims were reported. A technician in the vicinity managed to escape just before the explosion after hearing a hissing sound made by the escaping synthesis gas composed 70% of hydrogen (flow-15,000 Nm³/h). The material consequences were confined to the immediate surroundings of the turbocompressor: electrical wiring and cladding melted down, insulating of pipes severely damaged, etc. The ammonia manufacturing unit was stopped for over a month.

Five days before the accident, the failure of CO2 absorption in the decarbonation column of the NH3 production plant being re-started led the technicians to open the vent downstream to the column before triggering the high temperature safety device. This rather excessive venting (operating error) led to the fall of the suction pressure of the NH3 synthesis turbocompressor and activation of the emergency shutdown of the workshop. The valve on the line between the turbocompressor and the methanisation reactor opened under the effect of the high pressure without the knowledge of the technicians.

Production resumed in the following days but an abnormal balance in the synthesis gases led the operator to carry out detailed investigations only to find that the valve previously under stress was no longer air-tight. Gas escaped via a 47 m high stack. The workshop was shut down one again to replace the valve in question.

The unit re-started again. The methanation reaction was triggered at 10.00 pm. The NH3 synthesis turbocompressor started at 1.30 am. The accident occurred at 3.14 am at the flange of the newly assembled valve (6" diameter, i.e. about 50 mm).

The accident occurred due to insufficient valve loading upon start-up that may have caused vibrations that loosened the flange screws. Moreover, the screws were undoubtedly not tight enough. The lack of traceability of the jointing operations (tightening torque) was also highlighted.

The accident feedback included the company in charge of valve reloading requiring certification from the inspection department of the plant, jointing procedures improved, specifications on jointing and valve overhaul made more stringent and an additional pressure sensor installed.

ARIA 32966 - 20/04/2007 - 38 - LE PONT-DE-CLAIX

20.14 – Manufacture of other basic organic chemicals

In the containment of a chemical unit, a phosgene (COCl2) sensor was triggered at 6.40 am after maintenance operations resumed as part of a technical shutdown.

This detection is further to a COCl2 leak that occurred (ARIA32965) the previous day in a valve upstream to an exchanger being replaced. Only one out of the thirty sensors fitted in the containment reacted. The staff was evacuated. None of the detection badges worn by the technicians reacted. Operations were suspended. The working group set up the previous day was reconstituted and the facilities were inspected again.

The sensor that sounded the alert was close to the outtake of an air duct whose air intake was near the leak site. The accident occurred due to the release of COCl2 at the joint upstream to the valve that leaked.

Several corrective actions were implemented:

- strengthening bolting of stoppers (during stop phases, bolting is reduced to save time)
- coating joints with adhesive to increase air-tightness
- stopping supply of nitrogen to pipelines to reduce pressure (weather conditions reduce the chances of humidity setting in facilities).

ARIA 33311 - 21/06/2007 - 76 - LE GRAND-QUEVILLY

20.15 - Manufacture of nitrogenous products and fertilizers

In a fertilizer plant, 62% nitric acid leaked around 8.10 am from a sectional valve at the inlet of calcium ammonium nitrate saturator in stable operating mode.

The 20 min leak resulting in the loss of 1 tonne of acid led to the release of significant quantities of nitrous vapours in the unit upon contact with the insulation of a steam pipe below.

The alert was sounded by an employee in the vicinity of the facility who noticed thick smoke being released from the unit buildings. The internal emergency plan was triggered at 8.12 am and lifted at 9.47 am.

The operations in the unit were stopped. The released acid, as well as the 2 m³ of water used to cool the facilities and reduce acid evaporation were collected in a retention tank and channelled to a pre-isolated recovery tank.

The economic consequences further to the stop of operations in the unit were limited.

The leak occurred due to the premature corrosion of the metal joints of the sectional valve. According to the operator, the material of the joint assembled a few days back did not match the specifications indicated in the purchase slip of the article.

Moreover, the inspection authorities for classified facilities noted that the nitric acid flow meter located downstream to the sectional valve and at the saturator inlet showed no variation in the inflow in the saturator despite the acid leak taking place upstream. The flow meter fitted with alarm and safety devices triggered at various thresholds by the closing of nitric acid valves failed to detect the leak and warn the technicians. No other safety device alerted the technicians of the leak. The unit was in fact not equipped with a sensor likely to detect such a leak.

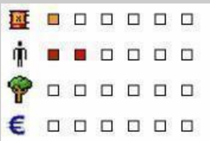
Further to this accident, and before re-starting the unit, the operator had to carry out an exhaustive inspection of similar joints likely to have been replaced during recent maintenance operations. In addition, the operator also had to conduct an inspection and overhaul of all facilities likely to have been damaged due to the acid spill.

Gas distribution pipelines

⑧ Gas leak in a pipeline

ARIA 34042 - 22/12/2007 - 93 - NOISY-LE-SEC

35.22 – Pipeline distribution of gas fuels



Gas leaked from a pipeline below a pavement at around 9.00 am which was followed by two explosions at around 9.45. A 5-storey residential building caught fire and collapsed partially. Approximately 100 people were evacuated. Gas supply to 200 customers was cut-off. The fire was extinguished by 176 fire-fighters and 51 fire-engines. The fire-fighters also carried out the clearing and research operations. The rescue operations ended on 23/12 at around midday. Eight people sustained injuries and 36 flats were destroyed. Boring operations aimed at soil testing in the residential area may have possibly triggered the accident. An enquiry was conducted to analyse the malfunctioning observed and suggest solutions.

Gas distribution pipelines

Each year, over 6,000 cases of damage to gas distribution pipelines following leaks are recorded in France due to works in the vicinity of the distribution networks. The years 2007 and 2008 were particularly grim with four successive serious accidents in Niort (ARIA 33803), Bondy (ARIA 33784), Noisy-le-sec (ARIA 34042) and Lyon (ARIA 34280).

Even though road works in the vicinity of the distribution networks are the main cause of the accidents, other circumstances have also lead to accidents: melting of polyethylene pipelines in a fire causing the transported gas to be released (ARIA 18653) or damage to a pipeline during an electrical short circuit (29484) for instance. Several cases of gas leak from sectional valves (ARIA 27888, 27887 28698, 30885), valves (ARIA 30028) or insulating joints (ARIA 35290, 35744) are also recorded.

An investigation report drafted by the French civil defence and safety authorities in February 2008 following the Bondy (ARIA 33784) and Noisy-le-sec (ARIA 34042) accidents took stock of the situation and suggested areas of improvement. The French Ministry of Sustainable Development also set up national work groups in charge of improving existing regulations on works near gas distribution networks (decree no. 91-1147 dated 14 October 1991).

Some of the accidents occurred in the vicinity of industrial facilities (ARIA 28360, 29900, 35790) or in public places (railway stations, petrol stations) or sometimes involved significant quantities of hazardous material (ARIA 27455, 28148).

Construction sites must be managed in a stringent and safe way: attacks on structures by public works equipment (power shovels, augers, non-directional drilling equipment such as boring tools, etc.) are the most often seen (ARIA n° 33784 , 33803, 34802), but other cases are also observed: truck spilling its contents in a pipe trench (ARIA 1219) or a basement wall collapsing under the weight of a crane (ARIA 3423).

Some accidents illustrate the lack of reliability of the information provided and absence or inadequate onsite inspection by technicians working on gas distribution networks. Inaccurate and even wrong gas distribution network maps are regularly reported (ARIA 33803, 34802).

Several initiatives as part of a preventive strategy must be taken to reduce the occurrence of accidents. This mainly depends on an analysis phase before staring works, risk prevention during the works, reducing effects of accidents, protection of people and property, appropriate coordination among emergency services, as well as optimal management of the post-accident phase.

Moreover, it is also recommended to bear in mind the condition of the gas distribution networks especially when dealing with old pipelines. Accidents have made reference to the corrosion of steel tubes (ARIA 1092) or equipment inherent to piping such lamellar graphite cast iron also called “grey cast iron” (ARIA 21551, 28855). Grey cast iron is the cause of pipeline rupture in several serious accidents including the explosion in Mulhouse on 26 December 2004 (ARIA 28855) resulting in several deaths. Grey cast iron has also resulted in the decree dated 1st December 2005 on prohibiting exploring of grey cast iron gas distribution pipelines. The decree has led to their complete disappearance.

The absence of a formal Start of Works Notification (DICT) by the undertaking company and even more frequently no formal Request for Information (DR) by the contracting authority or presence of wrong information (ARIA 21216, 18776, 26397, 34802), or inaccurate gas distribution network maps (ARIA 33803, 34802), poor management of construction site and inadequate training of staff speak in favour for better risk prevention at source.

To keep the effects of a gas leak to a strict minimum, rapidly isolating a section (ARIA n°35181), eve n cutting off power supply (gas, electricity) in the district to prevent the risk of creation and explosion of gas accumulation, implementing an initial safety perimeter and plugging the pipeline (ARIA 21216) require efficient organisation of the departments and bodies involved as well as acquisition of safety reflexes by the staff concerned (evacuating the premises calmly, promptly informing the fire department upon detection of a gas smell). As part of the action plan driven by the French Ministry of Home Affairs by the French Sustainable Development Ministry, a procedure called “reinforced gas” has been set to provide a pro-reactive response in managing accidents when sensitivity criteria have been met (and in particular when the gas leak is likely to spread to residences). This procedure has currently been tested in several regions in France and guarantees availability of significant resources provided by emergency services and the gas distribution network operator to create a safety perimeter, evacuate the people present at the earliest and manage the leak as soon as possible.

Management of emergency operations deserves optimal coordination between all involved departments (police, fire-fighters, etc.) and operators: triggering an emergency plan especially in the even of a casualty (ARIA 33784), setting up a centralised control station for all departments, adjusting the safety perimeter and managing communication are all vital elements.

The accidents whose references are not underlined may be consulted at:
www.aria.developpement-durable.gouv.fr

ARIA 1092 - 25/02/1989 - 43 - VALS-PRES-LE-PUY

35.22 – Supply of gas fuels through pipelines

A leak in a water network body end corroded a gas pipeline in the city. The gas leaked and exploded destroying a two-storey building and causing damage to two other. Three persons including one fire-fighter sustained injuries.

ARIA 21216 - 08/10/2001 - 57 - MARANGE-SILVANGE

35.22 - Supply of gas fuels through pipelines

Gas leaked from a 32 mm diameter polyethylene pipeline at a pressure of 3.9 bars and connected to a steel tube with a 100 mm diameter. While excavating the pavement on the public road, the earthmoving machinery lifted and then folded the steel pipe on causing the polyethylene tube to be ripped out. The company had not made a request for the DICT (formal Start of Works Notification). The company was a working in the capacity of a sub-contractor for another company. The technical gas department arrived onsite. The emergency services established a safety perimeter. Road traffic was prohibited in the district. Electricity and gas supply were cut off. Ten detached homes were evacuated and the families moved to a community hall during the time taken to clog the leak. The leak was partially sealed 2 hours and 20 minutes after the alert was sounded and fully sealed after 6 hours and 25 minutes. The fire-fighters used nozzles (including 2 that set up a fan-shaped water curtain) to set up water curtains to disperse the gas cloud. The technical gas department demanded compensation from the company. Since accidents had already occurred in the past, the company was also asked to train its employees and analyse the various accidents occurred.

ARIA 21551 - 04/12/1999 - 21 - DIJON

35.22 - Supply of gas fuels through pipelines

Shortly before midnight, a violent deflagration in a five-storey building destroyed the entire stairwell of a building that collapsed forming a 900 m³ heap of gravel and dust. The red alert was sounded. Significant human and material resources were deployed to clean up the wreckage and attend to the victims. Eleven dead bodies and 3 injured people including one seriously injured child were extracted from the debris. A legal enquiry and expertises were carried out to determine the precise cause and circumstances of the accident.

According to the gas department in question, a first expertise report claimed that the rupture of a 100 mm grey cast iron pipeline at 3.5 m from the building that was commissioned since 1955 led to the explosion. This report also stated that equipment was cased during operations carried out in the mid eighties upon the request of the members of the co-ownership. Two different materials used to lay the piping may have weakened it over the years causing it to rupture. The resistance of the pipeline to withstand external stress was weakened by the grey cast iron widely used from 1940 to 1970 (comprising 1/3rd of the network according to the operator). The use of grey cast iron in new pipes has been discarded for over 20 years and has been mainly replaced by polyethylene since 1980. As part of the nation programme on modernising its gas supply networks, the gas department had moreover planned to gradually replace all existing grey cast iron pipes over several years.

However, given that the gas department was aware of the fragile and dangerous nature of grey cast iron and it failed to further its objective of replacing all pipelines despite sufficient financial resources, the French Criminal Court sentenced the gas department to pay e fine of 204,500 euros for involuntary manslaughter and injury on 23 March 2006. The ruling was upheld on the 21 December 2006 by the Dijon Court of Appeal that based its verdict on the facts taken into account for the initial ruling (non-renewal of the pipeline, insufficient odour of gas, mistake in the map.)

ARIA 28855 - 26/12/2004 - 68 - MULHOUSE

35.22 - Supply of gas fuels through pipelines

A four-storey building was destroyed in a violent explosion that took place around 5.00 pm killing 17 people and causing light injuries to 15. The explosion also damaged two linked social dwellings (comprising 10 flats each) leading to the partial collapse of one of the buildings in the evening. Around 100 fire-fighters backed by rescue and clean up units were called in: dog team, heavy equipment such as backhoe loader, etc. A safety perimeter was set up. Rescue operations were impeded by the suspected presence of accumulated residual gas: fire nozzles were installed as a precautionary measure to counter the lingering risk. During the phase of securing the premises, 260 homes were deprived of gas. Operations continued all night until a part of the following day. Homeless families were offered alternative housing. The accident caused an emotional stir amongst the masses and the mayor was concerned over the presence of similar pipelines. Administrative and legal enquiries were commissioned to determine the causes of the explosion. The gas department mentioned that the inspection of the network on 10/12/2004 after five days following a tremor revealed no malfunctioning. Furthermore, no emergency call was made on the day of the accident. The legal expertise report was presented to the families of the victims on December 2005 by the public prosecutor. The report stated the instantaneous rupture of a grey cast iron pipeline laid in 1957 at a little over 5 m from the building causing a significant gas leak. The gas company was placed under judicial investigation in the capacity of a legal person. A programme to replace grey cast iron pipes that was launched in the 80s was still in place. The French Ministry of Industry its completion for end 2007 (2,000 km of such pipelines, i.e. 1.2% of the supply network must be replaced within the deadline), as well as treatment of sensitive areas for end 2006. The gas company set up an audit mission undertaking three annual inspections of the pipeline as opposed to one in the past. Furthermore, a compensation fund for the victims was also set up.

ARIA 29900 - 26/05/2005 - 73 - HERMILLON

35.22 - *Supply of gas fuels through pipelines*

Around 11.00 am, an earthmoving machine ripped out a low pressure pipeline (diameter = 40 mm) in the public road of a commercial zone causing a gas leak. A 60 m safety perimeter was set up and 54 persons evacuated. Gas indicator measurements revealed a danger zone at 2 m from the leak. The technical team from the gas department cut off supply in the sector, thus stopping the leak. The shops reopened around 3.00 pm. Operations in a foundry supplied by the gas network were disturbed during repair: two furnaces were temporarily stopped.

ARIA 33784 - 30/10/2007 - 93 - BONDY

35.22 - Supply of gas fuels through pipelines

Around 2.00 pm, an explosion resulting from the accidental puncturing of a gas pipeline (service pressure: 4 bars, commissioned on March 2007) was followed by a fire during road works. The red alert was triggered at 2.19 pm and around 251 fire-fighters along with 68 fire engines were called in. A safety perimeter was set up and then widened given the new developments and the risk of a second explosion. At 4.30 pm, the road works team crushed the 63 mm polyethylene pipeline to stop the gas flow. The emergency services then put out the fire. The provisional casualty toll of the accident stood at one death, 63 injured including 10 cases of serious burns (4 with very poor vital prognosis). Two residential buildings including one café-restaurant on the ground floor were damaged. Legal proceedings had been instituted on 9 November for involuntary manslaughter and injury, damage to property following breach of duty of care and safety requirement.

ARIA 33803 - 05/11/2007 - 79 - NIORT

35.22 - Supply of gas fuels through pipelines

At 6.00 pm, a power shovel operating in a public road damaged a gas distribution pipeline. The fire-fighters were informed and were onsite along with the gas company. During exploration, an explosion followed by a fire occurred at the level of a detached house located near the construction site.

The detached house was completely destroyed and eight people sustained injuries including 4 residents and one fire-fighter who were seriously injured.

The police set up a 50 m safety perimeter. The leak was stopped at 6.20 pm. The fire-fighters installed two variable flow nozzles and extinguished the fire at 11.00 pm. Eighty houses were deprived of gas for 3 hours. According to the press, none of the maps showed the presence of the pipeline.

ARIA 34280 - 28/02/2008 - 69 - LYON

35.22 - Supply of gas fuels through pipelines

A gas leak in the city centre at around 11.30 am was reported in a public construction site on a public road. The rescue services set up the safety perimeter and carried out an exploration operation. An explosion followed 45 min later and damaged several buildings. The fire engulfed the buildings near the site of explosion before spreading to the other buildings as well. The rescue operation required 180 fire-fighters and 300 policemen. The gas supply to the source of the leak on fire was cut off at 2.15 pm

Between 500 and 1000 people were evacuated including children, staff of a school and day care nursery. 38 residents were temporarily accommodated in a nearby gymnasium. A young fire-fighter evacuating the last occupants of a building lost his life and about forty cases of injuries were reported. A legal and administrative enquiry was carried out to investigate the circumstances and causes of the tragedy. On 30/06, as a precautionary measure, 7 people were evacuated from a building that risked collapse located in front of the site of explosion.

An investigation report prepared after the Noisy-le-Sec (ARIA 34042) accident put forth around 20 proposals aimed at preventing such accidents. The suggested measures included administrative (single computerise contact point to facilitate regulatory formalities before works, better information sharing among the players involved, etc.), preventive (regular surveillance of technicians, involvement of the contracting authority as early as possible, improvement of information provided on maps, etc.), pedagogical (enhanced feedback on construction sites, raising awareness of players involved through training, etc.) and operational (avoiding the use of oversized earthmoving equipment to perform operations, etc.) ones as well.

This report underlines the number of uncertainties on networks while admitting that errors occur at the implementation stage even though procedures are drafted. Several think tanks have been set up to study these recommendations and draft concrete proposals.

ARIA 34802 - 01/07/2008 - 39 - SAINT-LAURENT-EN-GRANDVAUX

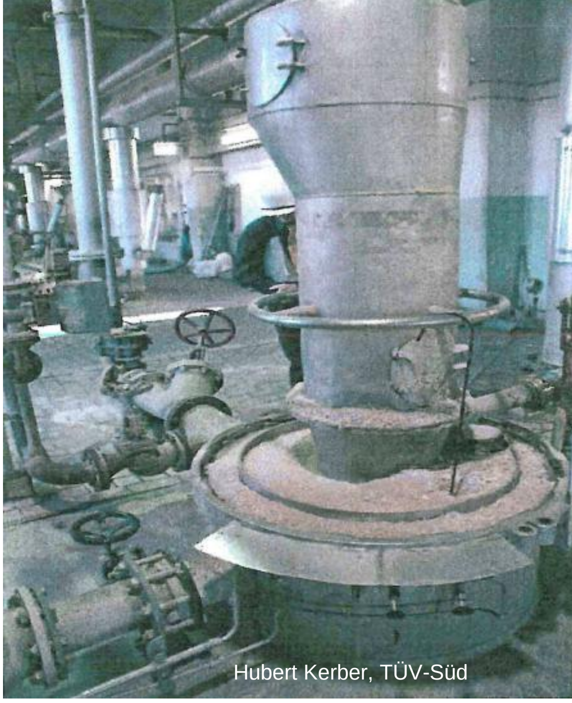
35.22 - Supply of gas fuels through pipelines

In an optical fibre laying site, a toothed trenching machine severed and ripped out a natural gas distribution pipeline (diameter 125 mm, pressure 4 bar). The employees switched off the engine of their vehicle. The gas department was informed and arrived onsite at 3.26 pm. It closed a valve upstream after spending 50 min trying to cut off the pipeline's gas supply. Repair operations started at 6.30 pm and the gas supply was restored as of 9.00 pm to some customers.

The inspection authorities for classified facilities arrived onsite and the operator had submitted the formal Start of Works Notification and a yellow warning fence was found buried 0.6 to 1 m deep in the debris on the pipeline.

Further to this accident, the report of the inspection authorities for classified facilities stated that it was not easy to read the maps provided with the formal Start of Works Notification (DICT). The map provided by the technical team of the gas departments in two parts specifies that the pipeline crosses the RN5 at the Y junction of the road. The two parts of each of the maps were accurate but the assembly scales were not properly adapted. The bifurcations of the successive roads led to an error in precisely locating the position of the pipeline.

The accident had significant social consequences: road traffic was stopped and 320 residences deprived of gas.


Hubert Kerber, TÜV-Süd

Disturbance in power supply

⑨ Accidental release of toxic emissions following a power cut

ARIA 35841 - 16/08/2006 - GERMANY

17.1 - Manufacture of pulp, paper and paperboard

In a cellulose manufacturing plant, sulphur dioxide leaked following a loss of air tightness of a cover of a reactor. Cellulose is manufactured in a process where wood chips are heated in a vessel containing sulphuric acid and sulphur dioxide. At the time of the accident, the reactor was loaded with wood chips and acid. The production then entered the heating phase where there is a rise in temperature. During this process, the cover is kept closed by the water maintained under pressure by an electrical pump. Air tightness of the system is achieved once a certain pressure level is attained.

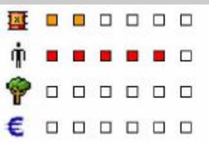
There was a power failure impacting the entire site during the phase of rise in temperature. The electric pumps maintaining the water under pressure were no longer operational. This led to an estimated release of 100 Kg of SO_2. The emission was detected by a car driver who informed the fire department and the police.
The consequences of the accident were reduced by the fact that a sufficient pressure level was attained to maintain the sealing device in place and a technician had the reflex of switching over the facilities to the "self-sealing" phase. The investigations that ensued after the accident revealed a lack of awareness on the vulnerability of electrical facilities especially with regard to the ripple effect of failure.

The remedial action taken by the operator included modifications in the reactor sealing system by replacing water with nitrogen to maintain the pressure, modification in the SO_2 alarm system. The site's safety management system was modified to take into account the lessons learnt from this incident.

⑩ Release of hydrogen sulfide in a refinery with transboundary effect

ARIA 35905 - 02/09/2008 - BELGIUM- ANTWERP

19.20 - Manufacture of refined petroleum products



At 11.57 AM a power failure occurred in a refinery. The supply of electrical power was cut off, as a result of the failure of the main power line during maintenance. Because of this the refinery was almost completely powerless, which led to an emergency shut down of the whole plant. The automatically operated safety systems started working: large quantities of products were dumped in the emergency torch and were burnt off. Safety valves opened and released gasses to the atmosphere. Personnel and people working at the refinery were evacuated and only an emergency staff remained at the plant. Information at the central operating desk about what was going on in all the components of the plant was sparse. In the first hour after the incident it was not known which safety valves were opened and which products were ventilated into the atmosphere. That information became available bit by bit during the cause of the afternoon. One of the safety valves that opened released an amount of ca. 70 kg H_2S into the atmosphere. The release point is situated at about 40 m above ground level. After 5 min, the cloud of H_2S formed reaches a downwind distance of about 3 km with a concentration valued at nearly 10 ppm 3 m above ground level. After 20 min the cloud has traveled 14 km and has reached the Netherlands. Concentration levels in the cloud vary between 0.64 ppm at ground level and 0.06 ppm at the top of the cloud at an altitude of about 850 m. Driven by a wind from the south-south-west at 45 km/hr, the cloud proceeds over the western part of the province of Brabant and after about 70 min has reached the city of Dordrecht, 50 km from the refinery. Concentrations of H_2S in the cloud are about 0.06 ppm, still well above the smell detection level. No warning of the H_2S spill was issued, partly due to a lack of information at the plant, partly due to a lack of communication between Belgium emergency services en the Dutch authorities. A population of about 100.000 people was in the path of the cloud and potentially affected by it. An estimated several hundred people were affected by the H_2S and experienced nauseous ness, and respiratory problems. 57 people needed medical care. However the Dutch emergency services were not prepared to deal with the situation, due to lack of information about the event and its possible consequences. This in turn led to insecurity and a loss of confidence in the capacity of the government to deal with incidents like these.

Disturbance in power supply

Residential power cuts are very often harmless even though constraining. However, any disturbance in the power supply to industrial sites can lead to a sudden stoppage of facilities and a seriously impact units, safety of persons and quality of environment.

Loss of power supply, often resulting from loss of supply of utilities (steam, air, cooling water, etc.), impacts units. It leads to disturbances in processes whose effects can be delayed (ARIA 31696), and cause malfunction that may have a cascade effect leading to even a complete shutdown of the facilities (ARIA 26198, 26465, 26579, 30375, 31900, 32679, 33344, 33727, 35022, 35841). The safety alert in the facilities is often accompanied by sending the untreated gaseous effluents to the flare network creating peaks of atmospheric pollution (ARIA 24120, 24926, 25178, 26198, 28416, 30894, 32679, 35905). Power cuts also effect units treating atmospheric emissions and/or liquid effluents (ARIA 18466, 33403, 35296) causing incidents of accidental pollution. Any impact on the safety functions of facilities (ARIA 19716, 25147, 30906, 35905) may sometimes result in release of hazardous substances (ARIA 4695, 6449, 33727), fires (ARIA 20835, 28416) or explosions (ARIA 26579) jeopardising the safety of people and integrity of equipment. The re-start phases that follow are sometimes critical and may lead to malfunctions and accidents (ARIA 3204, 7791, 20844, 23554, 27125, 30199, 31696). These accidents may be especially destructive (ARIA 7791, 20844) resulting in material damage worth millions of euros (ARIA 11147, 35022) or claiming victims (ARIA 5989).

There are several reasons behind disturbances in power supply ranging from low voltage to brief or prolonged power cuts that may or may not be repetitive. Equipment malfunction (ARIA 23554, 24926, 25178, 26198, 32679, 33344), work on electric lines (ARIA 25977, 35905) or in the vicinity (ARIA 5105, 31099), damage to cables due to snowfall (ARIA 20761) or wind (ARIA 22753) etc. are also reasons behind power cuts or disturbances in external supply networks. Internal electrical equipment are also sources of power failure due to short-circuits or malfunctioning of electrical equipment (ARIA 24120, 28416, 32125, 32631, 33282, 33344) sometimes resulting from poor preventive maintenance. Performing operations and working on these installations or in the vicinity (ARIA 735, 13689, 19325, 25977, 31900, 35841) are sometimes critical and require trained staff, sound preparation and efficient coordination of operations (ARIA 5989). Lastly, special care must be taken with regard to the devastating effects of lightning on electrical equipment (ARIA 15749, 19716, 25147, 26579, 30199, 30894): power line disturbance, rupture of electric cables, electrical arcs, overvoltage, loss of power supply, etc.

In an industrial site, the architecture of electric networks, the related protection plans, automatisms, and monitoring devices are all geared to anticipate disturbances in the power supply while protecting safety and environmental equipment on a priority basis and ensuring the fold-back of equipment. However, emergency systems do not always help achieve these objectives: failure to switch over to relay equipment (ARIA 17059, 28416, 32125, 34755), total or partial failure of emergency batteries and motors following breakdowns or previous operational errors (ARIA 12859, 15757, 21966, 26312, 34072, 34755). Sometimes, the very configuration of the emergency network creates a problems: emergency power supply overload (ARIA 8848, 24120), inappropriate delay devices (ARIA 26199, 30199), interface problem with the external distribution network (ARIA 24926), non-fail safe valve or equipment failing to revert to safety position by default (ARIA 7183, 15934, 25977). Lastly, it is important to properly manage these emergency situations, any operational error may lead to collateral accidents (ARIA 12859, 15749).

Several accidents illustrate the need to identify as a preventive measure the consequences of a power supply failure on the various safety functions and on waste treatment equipment. This approach helps useful in ensuring power supply to critical safety functions depending on the various available power configurations after activating the internal emergency devices or not. It is also important to regularly test and ensure maintenance of emergency systems, draft procedures and train technicians likely to intervene in fail soft mode. Power supply, vital to the functioning of the production tool, forms a strategic part of safety.

The accidents whose references are not underlined may be consulted at:

www.aria.developpement-durable.gouv.fr

ARIA 12859 - 19/03/1983 - 38 - CLAIX

20.13 – Manufacture of other basic inorganic chemicals

500 kg de Cl_2 leaked from a scourer of a chemical plant producing chlorine and its derivatives for 1 hour. The plant has three interconnected substations lowering the voltage from 63 to 5 KV; 2 of them are supplied by a substation based in the town, one of them by an electric line (L1), the second by 2 electric lines (L2 & L3). The third substation is connected to the thermal station of the site. At 2.55 pm, a serious fault on substation P1 caused several circuit-breakers to trip in the other substations of the site as well as on substation P1 itself. Since it was not possible to determine the origin of the fault from the control room of the thermal station, the technicians performed opening and closing operations on the lines which in turn caused the gas turbines supplying power to the plant to stop. At 3.12 pm, line L3 was re-commissioned and the power supply restored on substations 2 and 3 but not on substation P1 supplied by line L1 that was open before the incident. Since the fault was still not identified, a test was carried out to close line L4 supplying substation P1 from the substation P2. A new fault between the phases of the bus of substation P1 shuts down line L3 again. The technicians, once informed, went to substation P1 where they found out that one of the voltage transformers that measured the voltage change on the line 63 KV was destroyed with the transformer oil still burning. The substation P1 was totally isolated. The power supply was restored in the site at 3.47 pm.

During a general power failure, the equipment was secured and the eight diesel generator sets were automatically started to supply only the equipment required to stop the units. Even if seven of them started normally including one manually, the eighth supplying the Cl_2 production unit and three other units stopped two seconds at the latest since the fuse had blown. Overpressure in the upstream circuits containing liquefied Cl_2 lifted the frangible roof of the scourer and also damaged a joint on an ammonia pipeline in a desalting unit. The released NH_3 and Cl_2 formed ammonium chloride that helped see the toxic cloud rise 1,000 m high and drift 10 km away before being dispersed by the favourable weather conditions. Two technicians involved were slightly poisoned by the fumes.

ARIA 15749 - 01/07/1987 - 38 - LE PONT-DE-CLAIX

20.14 - Manufacture of other organic basic chemicals

In a chemical plant producing chlorine, a electrolysis room had to shut down operations subsequent to a micro electrical power outage during a thunderstorm. An inappropriate manipulation caused a rise of pressurised gaseous chlorine into an unpressurised column located upstream of a compressor that was still running. The column head was lifted and 6 kg of chlorine were released into the atmosphere.

ARIA 20844 - 29/07/2001 - 17 - ARTHENAC

11.01 - Distilling, rectifying and blending of spirits

In just one hour, a fire destroyed a 2-storey, 800-m² building housing a distillery containing 50 hl of pure alcohol. The emergency intervention of some forty fire-fighters using major quantities of emulsifier still did not enable saving the production line, the storage of bottles ready for shipping or the distillery offices. A thunderstorm passing 90 minutes earlier would have caused an electrical overvoltage with power outage; even though power was restored when the operator activated the circuit-breaker, a smouldering fire was still created that eventually lead to the full-scale blaze.

ARIA 23554 - 15/11/2002 - 76 - SAINT-PIERRE-LES-ELBEUF

20.14 - Manufacture of other basic organic chemicals

A generalised power failure at 4.21 pm in the entire geographical sector caused the units of a plant manufacturing surfactants, polyesters, polyols and polyurethanes to stop. When the units were re-started, 180 kg of 6% sulphur trioxide (SO_3) was released into the atmosphere for 10 min when a sulphonation unit pump did not re-start. The irritant cloud drifted away and affected a 7-storey building attracting 15 complaints from residents. The fire-fighters confirmed the irritating nature of the cloud, took measurements that revealed no anomaly and ended operations at 7.30 pm. During the pollution incident, the local network Air Normand monitoring atmospheric pollution (measurement frequencies: 10 s) did not detect any abnormally high concentrations of sulphur dioxide and sulphur trioxide.

ARIA 24926 - 25/06/2003 - 38 - SAINT-CLAIR-DU-RHONE

20.14 - Manufacture of other basic organic chemicals

A power cut in a chemical plant caused the automatic fold-back of carbon bisulphide (CS_2), sulphuric acid (H_2SO_4) and methyl mercaptan (MeSH) production units. The power supply of the plant was managed by an independent EIG. The decompression of the facilities led to the release of 700 kg of sulphur dioxide (SO_2) in less than 15 min (200 kg via the MeSH unit's flare and 550 kg by the flares of the H_2SO_4 and CS_2 units). Given the relative atmospheric stability, an SO_2 cloud was formed over the site. The internal emergency plan was triggered, staff confined or evacuated and the neighbouring towns informed about the accident. The onsite SO_2 measurements indicated values close to 0, but the measurements made by the local air quality monitoring network situated at Roches de Condrieu showed a SO_2 peak of 2.5 mg/m³ 30 min following the accident. The situation was back to normal after an hour.

A new power supply substation and new protections were set up two days before the accident to create lines supplying a new production unit. Since then, the site was supplied by two 20 kV lines with a coupling switch in the platform substation to balance the load between the two links. The accident resulted from an earth fault detected by the power supply company that interrupted power supply to the chemical platform by the protective relay. The units supplied from this substation were deprived of power for 11 min. It was later on confirmed that the 20 kV power supply was protected at 0.7 A initially by an electric transformer due to the mixed supply of the chemical platform and an overhead network supplying residences while the site's internal protection was set at 3 A to avoid sudden power cuts. The plant requested the power supply company to raise the protection level to 3 A or replace it with an alarm. In the meanwhile, the coupling switch will remain in tripped position.

ARIA 25147 - 02/06/2003 - 69 - GENAY

20.16 - Manufacture of plastics in primary forms

Around 5:45 pm, a thunderstorm caused both immediate and deferred damage inside a plastics plant. Operators reported a momentary loss of electrical power, followed by down telephone lines running through the switchboard, along with the destruction of 3 parking surveillance cameras. Later on about 4:45 am, an alarm indicated a lack of water serving the workshops at 1.5 bar. A single reactor at the time was performing polymerisation; the system shut down the monomer and catalyst injections, and the temperature that was stable at first then started to slowly decrease. A still that had been operating in a workshop on a cooling tower circuit was able to finish its distillation process. All the devices were thus turned off. According to analysis, the lack of water was caused by shutting down the water tower supply pumps during the thunderstorm; the system to alert the operating company of a low water level malfunctioned due to a lack of electrical power and the fact that the industrial zone consumed the total volume available from the water tower between 5:45 pm and 4:45 am. Restoring the zone's water network occurred gradually and water pressure was reset around 9 am. The incident, which exerted no impact on the environment, did however place the company in a position of highly-compromised safety. The inspection required the operator to conduct a safety analysis of all facility operations. This analysis and the associated conditions were then expected to be integrated into the study of site hazards.

ARIA 25977 - 21/11/2003 - 39 - COURLAOUX

38.11 – Collection of non-hazardous waste

During a weekend, 300 m^3 of leachate derived from a class 2 landfill was released into the SEILLETTE basin via the storm drain. On Monday morning, the technicians isolated the basin responsible for the accident to stop the release by closing the manual valves. The chances of a retention wells located 5 km downstream being polluted were not excluded. Water samples were taken both upstream and downstream the accident site. The accident occurred due to a power supply failure following an intervention on Friday afternoon by technicians from the electricity department who failed to restore the power supply before leaving. Due to lack of power, the valve system controlling the leachate storage abruptly opened allowing the waste water to be released into the basin directly connected to the storm drain network. This network ended in a single rejection point in the middle of the natural environment fitted with a automatic closure valve coupled with a pH and resistivity analyser and an alarm. This valve did not function. The inspection authorities for classified facilities noted the facts and ordered the operator to secure the site and submit a report on the causes, circumstances and consequences of the accident, as well as the measures taken to reduce the chances of reoccurrence of such accidents.

ARIA 26198 - 27/06/1995 - 67 - REICHSTETT

19.20 – Crude oil refining

At around 3.20 pm, there was a loss of external power supply in a refinery. The site was supplied by two distinct lines on two separate sets of tower members without interconnection and supported by distinct towers operated by a power supply company independent of the refinery. There was an auto-reclosing device onsite with a 3-second time lag. Beyond this time frame, the circuit-breakers had to be reset manually by the technician. This required only a few seconds. On the day of the incident, the disturbance lasted 22 s: 2/3rds of the site's units automatically shut down (distillation, high pressure hydrogen units, gas-plants, H_2S conversion units, distillation residue conversion units). The catalytic cracker shut down. It was supplied by a gas turbine (gas supplied by the unit) and the buffer load bearing capacity ensured supply for 10 minutes. Subsequently, a pump directly connected to the power network supplied the catalytic cracker. At 3.25 pm, the power supply was restored in the entire site and the various units resumed functioning. At 4.04 pm, there was external another power failure that lasted 22 s. The units stopped along with the catalytic cracker supplied by the electrical pump. The gas turbine that was still functioning due to the depressurisation gas allowed the boilers to function until the power supply was restored (16h06) but was stopped by the lack of gas at 4.22 pm. Meanwhile, the supply to all units reverted to the main power grid.

The incident resulted in the burning of 12.8 tonnes of hydrocarbons and the emission of 3.2 tonnes of SO_2 from the flare during the day. Following the abrupt stopping of the catalytic cracker, various checks were performed. During one of them, the safety pressure of oil caused the cracked gas compressor to stop for 1 hour and 27 minutes: 11.9 tonnes of hydrocarbons were burnt and 2 tonnes SO_2 released for a short duration. This resulted in black smoke that drifted to a nearby village due to the north-east winds blowing at 4 to 6 m/s. Residents complained or panicked because of the situation. SO_2 concentrations recorded on the town's analyser revealed peaks as high as 285 µg/m^3. The operator and the electricity company published a press release and informed the mayors of the neighbouring towns.

ARIA 26579 - 26/05/1977 - NC -

19.20 - Manufacture of refined petroleum products

An explosion took place on the furnace of a refinery's atmospheric distillation unit. A violent thunderstorm was responsible for generating various incidents in this unit, as a result of power outages. The furnace was thus turned off and then back on about 4 hours later. Approximately 45 min after start-up, the boilers were activated due to the lack of fuel and experienced a pressure loss on the steam network. An air pressure drop followed at the level of the system instrumentation, with the collapse of the gas fuel network, along with a pressure drop at the level of the pilots, including those of the specific furnace which were extinguished. The explosion actually happened inside the furnace by means of self-ignition of the accumulated gases. The origin of this accident stems from the poor meteorological conditions: an unfortunate lightning/thunderstorm combination.

ARIA 28416 - 25/10/2004 - 65 - LANNEMEZAN

20.14 - Manufacture of other basic organic chemicals

In a Seveso chemical plant, a fire broke out at 12.59 pm in a substation supplying a hydrazine hydrate unit. An electrical fault on a cooling water pump caused a generalised short circuit on an electrical tower. The fire alarm was triggered at 1.00 pm. The fire spread to the other towers of the panel through the subfloor. The 400 V circuit breaker located upstream was blocked and did not function. The fault current passed through the 13,000 / 400 V transformer, there was overpressure and an oil leak (Buchholz relay against overpressure not connected) followed by a primary side homopolar fault causing the 13 kV circuit breaker to trip. The absence of voltage caused the diesel generator set to stop but the switchover to the emergency system failed as the automatism was damaged by the fire. The smoke spread to the UPS room whose door remained opened. The UPS stopped when a high temperature (> 40 ℃) was reached causing the loss of control. The eq uipment switched over to safety mode. Due to the lack of power supply, the cooling system, agitation and the internal and external emergency plan siren were no longer functional. Since the ongoing reaction was exothermic, the reactor temperature (100℃ instead of 50℃) and pressure (0.6 b) increase d. The internal emergency plan was triggered at 1.35 pm. The fire was brought under control by the onsite fire-fighters at 1.50 pm. The opening of a safety valve of a hydrazine unit column released about 280 kg of NH_3 into the atmosphere. A fire nozzle sprayed water on the tower body to cool it. The external emergency plan warning panels on the road to the plant were activated. At 2.15 pm, a water curtain was implemented to disperse the cloud and the NH_3 concentration was measure in a neighbouring village (< 10 ppm). At 2.38 pm, since the NH_3 concentration was 3 ppm, the external emergency plan warning panels were deactivated. At 2.40 pm, additional water curtains were set up after a rupture disc (0.5 bar) exploded on another tower. The fire water was stored in a workshop tank. During the accident, the NH_3 concentrations measured were 10 ppm (olfactory threshold = 5 ppm, TLV-TWA = 25 ppm).

No casualties were reported. Operations stopped for several days. Several measures taken such as designing an emergency cooling circuit, improving circuit breaker maintenance, connecting Buchholz relay, sectoring UPS system, electric boards, generator sets, etc.

ARIA 30199 - 24/06/2005 - 57 - SAINT-AVOLD

20.16 - Manufacture of plastics in primary forms

An electrical network supply cut-off affected a basic plastics plant around 7:50 pm on a petrochemical platform. The interruption, which lasted a long time for the batch in progress (over 2 min), triggered protective measures for the plant workshops. The Internal Response Plan was activated and the units shut down operations at 8:15. Under these circumstances, the workshops sent the current batches to the site's two flares. The combustion of effluents generated heavy smoke that dispersed into the atmosphere under particularly stormy weather conditions. The backup diesel generating sets of the polystyrene workshop that provide a power relay in cases such as this did not engage fast enough to cool the reactors on lines 1 and 2 during the workshop shutdown phase. A reaction acceleration occurred, and the rupture discs of two line 1 reactors and a third on line 2 burst, causing the atmospheric release of 8 t of styrene. Since the weather conditions were unfavourable (i.e. weak wind), the cloud indisposed three residents from the l'Hôpital locality nearby and another two individuals living in Lauterbach (Germany), including a child who had to be hospitalised for 4 days. The sensors positioned near the petrochemical platform recorded, between 7 and 9 pm, high concentrations of dust, SO_2 (585 µg/m³ in a 15-minute span) and orthoxylene (535 µg/m³ in 15 min), most likely corresponding to styrene (i.e. a close chemical structure). The high SO_2 contents may be due not only to the workshops operating on the site, but also to the coking plant. It turns out that a condensate drip pot self-ignited around 4 pm on the coking plant's gas pipeline feeding the neighboring power plant. The emergency teams had the situation under control very quickly. The electrical supply interruption caused production losses on the order of 0.5 to 2 million euros. In application of the emergency decree signed July 6, 2005, the operator: established a report on the reasons why the electric generating sets malfunctioned, improved the start-up sequence, and more fully developed both the hazard study and the Response Plan. These actions enabled reopening the workshop. The Hazardous Installations Inspectorate proposed a complementary order that extends to the entire chemical platform a control over backup generating set operations and the completion of a study to lay out the points of potential release in the case of an incident, along with the type and quantity of products potentially discharged.

ARIA 30894 - 10/09/2005 - 13 - BERRE-L'ETANG

20.14 - Manufacture of other organic basic chemicals

A violent thunderstorm caused several incidents at an industrial site. The general electricity distribution station was struck by lightning that resulted in many electrical disturbances in particular the loss of equipment, the protection of several installations and, consequently, flare releases for a few hours. Just after sundown, two fires broke out, one on a pump packing the other on a heat-insulated line without any consequence whatsoever being recorded. Moreover, the site's treatment plants had to face a sizeable quantity of water inflow, necessitating the installation of floating dams on the nearby pond opposite the plant's outfalls.

ARIA 32125 - 28/05/2006 - 76 - LE GRAND-QUEVILLY

20.15 – Manufacture of nitrogenous products and fertilizers

There was a generalised power cut in a nitrogenous products and fertilizer manufacturing plant following failure (heating) of a 90 kV transformer constantly supplying all facilities of the site. For unknown reasons, the remote switchover to the two emergency transformers by the power company was not successful thus causing the power failure. The turbo-alternator of the site was unavailable during the incident and thus could not replace the emergency power supply. The two 630 kVA and 110 kVA diesel generators started automatically thus securing the facilities and avoiding any equipment damage. A few minutes after the ammonia unit shut down due to "electrical fault", the operator sounded the mini sirens located in each unit and designed to warn the technicians of an emergency for a limited time period. These uninterruptible mini sirens that operate non-stop for 3 minutes and than are audible in the adjoining areas created confusion around the site causing residents to call the emergency services and town halls thus involving the municipal police, prefecture and the media. The unusual silence in the facilities was undoubtedly why the sirens were heard in the neighbourhood. The operator had to specify the conditions for implementing the automatic relay between transformers, justify the provisions taken to ensure regular preventive curative and maintenance on the turbo-alternator and the diesel generator sets, review the mode of use of mini sirens and their activation/deactivation conditions.

ARIA 32679 - 04/11/2006 - 76 - PETIT-COURONNE

19.20 - Crude oil refining

An incident on a German very high voltage network caused disturbances in the power grid by generating a low frequency threshold causing several units in the refinery to switch over to the safety mode. In line with the architecture of the power supply system, only the units supplied by the utility turbo-alternators were operating. These included the utilities, the CLAUS 4 hydrogen sulphide conversion unit, SCOT tail gas treatment unit, the PLAT fuel catalytic reforming unit, the HDS gas oil desulphurization unit and the CRYO and HMP hydrogen production units. The operator set up a crisis unit without triggering the internal emergency plan. The Propane Deasphalting Unit (PDU), Furfural Extraction Unit (FEU) and Viscosity Breaking unit (VBU) re-started on a priority basis. The operator decided to leave the CLAUS 5 unit shut while the CLAUS 4 was still operating. This loss of power supply resulted in a hot oil leak at the oil unit exchangers, spilling of the catalyst from the catalytic cracker unit FCC and the solvent (methyl-ethyl-ketone and toluene) initially onto the ground and then to the drains from the solvent dewaxing units. This accidental release resulted in the COD measured in the oily waters of the platform to exceed for several days. It is also responsible for significant flares (hydrocarbon rate > 110 g for 40 min) and the unstable load of the CLAUS 4 sending hydrocarbons for incineration (due to the overflowing of the amine tower), and triggering a high temperature alert. A sulphur dioxide concentration peak (823 µg/m³) was recorded by the sensors of the air quality monitoring association in the town on 6 November since the SCOT unit treating the tail gases of the CLAUS 4 unit could be re-started only on 7 November due to poor load. Lastly, dispatch of butane and procurement of jet fuel from the refinery were stopped.

Additional references (detailed sheets):

ARIA 28416: Fire in an electrical room and emission of gas, 25/10/2004, Lannemezan, France

The effects of time on industrial facilities

⑪ Rupture of a silo causing a release on a propane tank

ARIA 35027 - 19/08/2008 - 45 - SAINT-HILAIRE-SUR-PUISEAUX

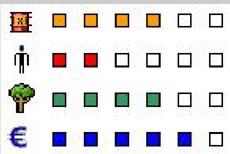
46.21 - Retail of cereal, unmanufactured tobacco, seeds and cattle feed

2,100 tonnes of wheat and 1,000 tonnes of maize spilled over to the ground at around 1.30 following the rupture of the walls of a 14,900 m³ “sheeting pile” silo built in 1989 and comprising 6 square storage bins (4 x 3 000 m³ + 2 x 1 400 m³) as well as two 66 m³ grain loading hoppers. A 95 m³ propane tank situated at about 15 m from the silo and supplying the grain dryer was partially buried due to the spilling of the grains causing a pipeline to break and LPG to leak. The emergency services set up a safety perimeter (150 x 300 m) and stopped the leak by closing the valve located just before the rupture area. The owner of the tank secured the container by emptying it and burning the gas using the flare network. The operation started at 6.00 pm and ended the following day at 5.00 am. No casualties were reported. An emergency prefectoral order recommended measures to secure the site and mainly stop all activity, shut down and monitor the premises, empty the cereal silo and inspect its condition. The re-commissioning of the silo was subject to a prefectoral decision.

⑫ Rupture of a crude oil storage tank

ARIA 32675 - 12/01/2007 - 33 - AMBES

46.71 – Fuel wholesale and related activities

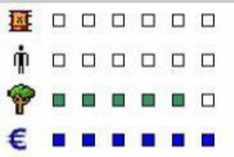


The bottom of a 13,500 m³ containing 12,000 m³ of light crude oil tank ripped open at 8:00 am within an oil depot. The earthen dikes surrounding the retention basin withstood the wave effect; 2,000 m³ of oil still overflowed however the dikes. For the most part, this volume remained onsite and in the gutters, although 50 m³ reached the channels of the neighbouring swampland polluting 2 km of ditch network and reaching the superficial water table and 50 m³ did flow into the GARONNE. The tidal action contributed to polluting up to 40 km of banks on the GIRONDE, DORDOGNE and GARONNE Rivers. The operator triggered the internal emergency plan and covered the retention basin with foam in order to prevent against the risk of inflammation and limit hydrocarbon and hydrogen sulphide (H2S) vapour dispersion. The authorities evacuated all 12 employees of neighbouring companies, established a safety perimeter, halted river navigation and traffic on the road and railway in the area, informed local populations and the nearby power plant, and measured the air quality. The products spilled into the gutters and retention basin were channelled towards the facility's sedimentation basin and then transferred into empty reservoirs: in all, 6,000 m³ had to be pumped out. The operator undertook pollution cleanup efforts (manual collection, dams, pumping, absorbent materials, use of dispersants, etc.) under the supervision of experts. Environmental associations and hunters don't notice significant impact on fauna. The products and wastes were disposed of in specific installations. Groundwater was also controlled. A total of 13,000 m³ of fire protection water charged with emulsifier (COD: 2.7 g/l) was stored prior to undergoing an activated sludge type of treatment onsite by means of extended aeration. Operation loss is estimated at more than 50 M euros. A slight leak on the tank had been detected the previous day at 5:00 pm. The operator rescheduled at the following day in the morning the drainage into another tank due to the risks incurred by the operators and subcontracted personnel by having to block the tank's floating roof at night. Water was injected at the bottom of the tank for the night. A control of the tank bottom in 2006 (on 100% of the bottom and 10 % of welding) mentioned the presence of corrosion on the tank bottom as well as losses of thickness reaching 80%. As a consequence, repair work had been performed and then verified. Moreover, the inspection report noted that no procedure had been outlined for managing the type of emergency situation that appeared the day before the tank failed. This accident raises a number of questions about prevention means (conception: bottom, settlement; controls of the tank: frequency, modalities …), measures to take when a leak is detected (emergency procedure, emergency storage, drainage …) and protection devices against wave effects. A legal investigation was carried out.

⑬ *Massive release of fuel in an estuary*

ARIA 34351 - 16/03/2008 - 44 - DONGES

19.20 – Crude oil refining



While loading 31,000 m^3 of bunker fuel in a ship, a leak in a refinery transfer hose resulted in a major oil spill in the Loire estuary.

At 4.10 pm, a person on a barge observed the presence of hydrocarbons on the water surface and sounded the alert. At around 4.45 pm, a roundsman identified and isolated the leak at 500 m upstream to where the hydrocarbons were detected.

The internal contingency plan was triggered at 5.00 pm and the inspection authorities of classified facilities were informed. A recovery ship was stationed at the mouth of the river while two trawlers recovered hydrocarbon pellets from the river.

The public ban on access to several beaches and fishing in the river that was in place subsequent to the spill was gradually lifted between the 4 and 18 of April. Over 750 people were involved for three and a half months in cleaning up the 90 km of polluted banks (6,170 tonnes of waste recovered and stored onsite before disposal). The operator bore the cost of 50 M euros to cover for the damage incurred, clean up and compensate effected businesses.

Investigations revealed that the leak was detected only after 5 hours leading to 478 tonnes of fuel being spilled of which 180 tonnes flowed into the Loire estuary.

A 16 cm² longitudinal breach caused by corrosion localised under the insulator was observed upon examination of the hose. The corrosion resulted from a water leak in the vertical pipe. Water seeped beneath the insulator, caused corrosion and subsequently caused the fuel pipe to rupture. Despite several defects detected the previous month on the same rack, the operator failed to revise this inspection programme to take into account the specific risks presented by this line given its proximity with the river banks. The effected fuel line was completely stopped and the inspections on the entire rack revealed several corrosion points on other lines that required repair.

The operator was required to implement several additional initiatives and measures:
- Extending inspection operations to other pipes in the site along with measurement of thickness at sensitive points (supports, spurs, etc.)
- Moving the layout of the service water mark so that it is not in a vertical position with respect to the insulated pipe
- Using a leak detection system along with a remote alarm in the control room to constantly monitor pipes located near the river
- Modifying the ground below the rack to channel any accidental spill to an adapted recovery network
- Installing a device to monitor the quantity of products leaving the tank and entering the corresponding transfer hose

It was also planned to consolidate the available emergency measures in the event of accidental pollution of the Loire river.

The effects of time on industrial facilities

Whether the focus lies on tanks, pipes or other equipment and regardless of their level of utilization, it is indeed likely that all facilities over the course of time lose some of their initial characteristics in terms of operations and safety. The sizeable loss of confinement at Donges (ARIA database reference 34351) and Ambes (ARIA 32675) are just two recent examples from a long list of incidents.

Depending on the type and context of installation use, ageing appears in a number of ways. The most frequently observed sign of the tangible effect of time is material degradation, in one of its multiple forms. This loss of integrity causes the perforation of equipment, which can be of significant concern and cause leaks in the surrounding environment (ARIA 21233, 31370, 34990, 34351) or the accidental introduction of substances capable of disturbing processes (ARIA 10285). Such degradation can also lead to weakening potentially critical structural elements, such as anchorages or supports (ARIA 22730, 25215), the abrupt tearing of containers (ARIA 15725, 30934, 32675), dropping of components (ARIA 21709, 24894), and even the collapse of large-scale facilities like silos or furnaces (ARIA 23368, 26362, 27721, 35027). The other symptom found during this examination is the malfunction of electrical equipment (ARIA 5009), processes (ARIA 10317, 29802, 30417), treatment units, protection or facility intervention plans.

A site containing older installations is thus more prone to experiencing a sequence of accidental or high-risk situations (ARIA 18302, 24636, 34351, 35146) and extreme (or even critical) operating conditions, capable of triggering spectacular accidents such as Bhopal in India (ARIA 7022). Should it not be the root cause of an accident, deteriorated equipment can still considerably exacerbate the eventual effects of an accident (ARIA 22231).

Induced facility ageing, whose mechanisms are often well-known, is capable of accelerating as a result of design and dimensioning flaws or construction defects; other factors include underestimating the effect of stresses in cases of inadequate monitoring or maintenance. Corrosion mechanisms are primarily determined by the environment, operating conditions and actual installation layout. Maritime settings (ARIA 21233, 34351, 34990), dampness (ARIA 35286) or acidic environments (ARIA 14666, 21709) are especially prone to this phenomenon. Similarly, a change in surfacing or medium (ARIA 31370, 35286, 35293), individual contact points (ARIA 23175), interface between different metals (ARIA 23898), etc. all tend to cause corrosion. Moreover, high temperatures (ARIA 33330), erosion (ARIA 6544, 21196, 34990), stress-induced fatigue phenomena (ARIA 2903, 6077, 14666, 21196), poor implementation practices (ARIA 29590), temperature variations (ARIA 15586, 22249) or vibrations (ARIA 25215, 35423) are also likely to exacerbate the effects of ageing.

Whether owing to poor judgment, negligence or other reasons, accident occurrence patterns relate to a broad array of events in which the symptoms of facility ageing have not been detected in a timely manner or anticipated (ARIA 21380, 21524, 30360, 30417), on some occasions in spite of many "warnings" (ARIA 34351). Verification campaigns might also prove inappropriate (ARIA 27721) or simply incapable of correctly measuring the speed of structural alterations (ARIA 34249, 34620), due either to defective equipment or interpretation error (ARIA 34990, 35293). In a number of instances, the implementation of facility renovation programmes, established subsequent to observations or inspections, is scheduled too late (ARIA 26362, 35214) or only insufficient temporary repairs are performed (ARIA 15725, 30117).

Awareness of the full extent of degradation possibilities is needed, along with an identification of factors capable of speeding the deterioration process. A group of points merits special recognition; these would include: protective surfacing, structures, welds, supports, joints, and tank bottoms. Control and maintenance efforts within relatively inaccessible or visually imperceptible zones, placed beneath heat insulation or undergrounded, i.e. areas subject to accelerated degradation, must not be overlooked due to either their complexity or the stresses they induce; a set of enhanced and increasingly reliable control methods are now available and inspection hatches can, under certain circumstances, be fitted.

Even though effective prevention techniques have been adopted, large-scale industrial platforms remain highly exposed to risks as a result of the large number of devices or piping involved. Preventive steps need to be well planned and organized. It is highly advisable for prevention to be placed squarely into a comprehensive management approach towards handling potential accident occurrence by incorporating early detection steps (visible equipment, frequent inspection visits, use of detectors, cameras, alarms, etc.), coupled with steps aimed at limiting potential effects (retention, a catchment system for effluents originating at the site surface, water curtains, etc.) intervention, evaluation of possible impacts and their mitigation.

Besides the property damage and operating losses generated by an eventual accident, structural ageing represents a sizeable cost for industry: it is estimated that 5 tonnes of steel are lost every second throughout the world as a result of corrosion, for an annual amount equal to 2% of the world's gross output. Taking preventive action serves to extend installation life cycle and, above all, limit the occurrence of accidents with potentially catastrophic consequences. Given that Europe's industrial infrastructure is ageing within a number of major business sectors, placing emphasis on problems associated with ageing, while far from being a new approach, can still prove decisive today.

The accidents whose references are not underlined may be consulted at:

www.aria.developpement-durable.gouv.fr

ARIA 7022 - 02/12/1984 - INDIA- BHOPAL

20.20 – Manufacture of pesticides and other agrochemicals

In 1969, an American company set up a production unit manufacturing a powerful pesticide called Sevin in Bhopal. The unit included three 60 m³ tanks (50 tonnes) of liquid methyl isocyanate (MIC) (E610, E611 and E619), each connected to various safety systems: cooling facility, wet scrubber, flare and water spray system. The Indian government had granted approval for the production of 5,000 tonnes of Sevin per year. To keep pace with competition in the insecticide market and overcome a budgetary deficit of 4 million $/year, the parent company decided to stop the local production of Sevin, lay off numerous supervisory-level staff members (especially maintenance) and run the site at low cost... The accident took place on the night of 2-3 December 1984. After cleaning the pipes, water entered the tank E610 and triggered several chain reactions causing an increase in temperature (200°C) and pressure (13.79 bar). In 2 hours, the safety valve let out 23 to 42 tonnes of MIC and other toxic gases according to sources. Several safety systems failed: cooling facility stopped (06/84), wet scrubber out of order (23/10/84), flare out of service (a few days before the accident), temperature, pressure and liquid level indicators in the tank faulty, water curtain not powerful enough. The toxic emission took a heavy tool on the population. According to sources, 1,754 to 2,500 people lost their lives and 170,000 to 600,000 were poisoned. More than 4,000 animals (cattle, dogs, cats, birds) died as well. The chronic pollution caused by the toxic release had long term consequences on the population. The list of victims had grown in numbers by end of 1998. 16,000 people were reported dead and 15 to 20 people died each month following the accident. The Indian court ordered the company to pay 470 million dollars. In 1991, the Bhopal court summoned the chairman of the company to appear in court for manslaughter in a criminal case. In 2004, the Indian Supreme Court ordered the central bank to release, at the earliest, the amount paid by the company in 1989 and compensate the victims. The European Parliament asked India to ensure that site decontamination and clean-up are undertaken at the earliest.

ARIA 15725 - 04/23/1999 - SEINE MARITIME (76) - ROUEN

24.1J - Production of fertilizer and nitrogen compounds

An older lead-lined steel tank (diameter: 8 m, height: 9 m, bottom thickness: 8 mm, shell thickness: 5-7 mm) containing 450 m³ of phosphoric acid burst at a chemical facility. The acid wave destroyed the reinforced concrete retention basin (with a combined core and wall thickness of between 10 and 15 cm). An in-house inspection had detected considerable corrosion on a generator and led to requesting a thickness verification. The maintenance team proceeded by locally reinforcing the tank (6-mm polyester layer, etc.) without actually performing the requested controls. The proper works sequencing procedure was not respected and consideration was not given to the fact that this site had been programmed to shut down over the near term. The strength loss subsequently detected, related to a localized leak in the lead lining, affected $4/5^{th}$ of total tank height. No serious environmental impact was observed. An emergency order was issued, and all site personnel were reminded of applicable procedures and informed of the inspectors' guidelines.

ARIA 23368 - 20/10/2002 - 02 - JUSSY

01.11 – Cultivation of cereals (except rise), pulses and oilseeds

The concrete wall of one of the vertical storage bins cracked throughout its length of 25 m in the silo of an agricultural cooperative built in 1963 during the first out of the three construction lots of the facility. About 100 tonnes of maize spilled over and destroyed a wall allowing access to the control facilities at ground level, below the drain cones that form the foot of the bins. The site was immediately secured, a safety perimeter was set up, delivery from farmers was stopped, the 12 bins built during the 1^{st} lot were gradually emptied and the power and gas supply to the dryer was cut off. The inspection authorities of classified facilities recommended the prefect to issue of an emergency site shutdown order that was signed and dated 31 October 2002 requiring an expert evaluation of the facilities. While waiting for the findings of the expert evaluation commissioned, the operator decided to stop operating the bins of the 1st and 3rd lot built in 1982 and suspended the operation of bins built in as part of the 2^{nd} lot. Poor ageing of the reinforced concrete along with the corrosion of the reinforced steel is the reason behind the accident.

ARIA 24894 - 05/06/2003 - 11 - PORT-LA-NOUVELLE

20.20 - Manufacture of pesticides and other agrochemicals

In an agrochemical plant, there was an explosion in silo no. 3 in the sulphur handling workshop that housed equipment for mixing, mechanical grinding, storing and packaging 5 tonnes of chemicals. During the explosion, all units of the facility were operational except silo no. 3. The effects of the explosion spread upwards to the top of the lift connecting the 3 silos, as well as to silos 1 and 2. The resulting overpressure was released by the vents of the silos. During the explosion, the maintenance manager was at the foot of the lift whose vent channelled a significant portion of the explosion to the outside. No casualties were reported and the material damage was limited to the facility: 3 to 4 tonnes of ground sulphur stored in the silos and a few parts of the roof were destroyed. Material damage was estimated at 100 K euros and operating losses at 113 K euros. The obsolescence of the upper portion of silo 3 (made of steel in a corroded state while silo 3 and the other silos were in stainless steel) may have caused the explosion. One or several rusted metal plates sticking out from the wall may have ignited the falling microionised sulphur particles. Technical improvements were made in the facilities: maintaining the ground sulphur storage silos in an inert stage outside operating times, use of equipment adapted to product handled, replacement of defective silo and overhaul of facilities.

ARIA 25215 - 24/06/2002 - 67 - STRASBOURG

52.10 – Warehousing and storage

Two overhead fuel oil pipelines implanted under the deck of a highway bridge transferring products between two oil depots owned by the same company subsided and showed a 2m deflection. At the time of the incident, the pipes were empty but were used just 30 min ago. The operator who was informed by witnesses working near a barge observed that there was no leak and installed an oil boom as a preventive measure. The oil boom blocked the access to the dock. Securing the pipes required the bridge traffic to be stopped for 3 hours and deviation to be set up. Moreover two cranes with telescopic jib were also need and the movement of boats in the oil harbour had to be stopped for the entire night. The reason behind the incident may have been the obsolescence of anchorage of pipes in the deck of the highway bridge compounded by the vibrations of the bridge resulting from heavy road traffic.

ARIA 34990 - 18/06/2008 - 971 - BAIE-MAHAULT

52.10 - Warehousing and storage

In an oil depot, after unloading a ship, the security agent observed a leak under a fuel pipe connecting the wharf to the depot. The agent installed a recipient to collect the drips and informed the operations manager who in turn informed the head of the depot. Less than 5 litres of fuel had leaked to the ground. The head of the depot observed the leak and decided to install a water pipeline. He informed his superiors and the inspection authorities for classified facilities who visited the site the following day and observed several areas showing significant corrosion especially near each of the supports along the pipeline. Since the pressure in the pipeline was low during the leak, there was no significant impact on the ground.

The initial coating of the pipe was not adapted to the corrosive nature of the marine environment, temperature, high relative humidity, friction and drippings from the mooring ropes of ships. Moreover, according to the operator, the maintenance schedule of pipes was drafted following the recommendations of a specialised body that carried out thickness inspections in 2007 and that stated that the anomalies on account of corrosion were acceptable given the operating conditions of 10 bars. The facility overhaul procedure was underway but the leak occurred before the action plan could be fully implemented. On 19/06/08, the pipeline was inspected by a company expert whose observations contributed to defining the operating conditions in degraded mode for all forthcoming unloading operations. The three other pipelines connecting the depot to the wharf were inspected a few days later (thickness measurement at areas showing external and internal corrosion detected during the 2007 inspection by the specialised body). An operations schedule was drafted based on these measurements: repair of pipelines and supports, installation of collars in sensitive areas, resistance tests, replacement of sections, application of bituminous coating, application of a coating using basic metal deposits obtained by welding, specific protection under mooring ropes, excavation of soil under the pipes running along the banks, etc. The operator decided to reduce the pressure in the pipeline in question to maximum 3 bars and reinforce surveillance until the operating conditions were back to normal. The operating procedures were accordingly modified.

ARIA 35146 - 06/09/2008 - 76 - NOTRE-DAME-DE-GRAVENCHON

20.11 – Production of industrial gases

Around 1.25 pm, a technician detected a strong smell of gas that he identified as propylene and noticed a cloud of fog at the centre of steam cracker without being able to precisely pinpoint the site of the leak. He then went to the control room and sounded the alert. The detection alarms of several gas indicators of the zone were activated on the safety panel. The safety panel operator called the fire department at 1.28 pm and triggered the internal emergency plan at 1.33 pm. The technicians present outside were evacuated and water spraying systems were gradually deployed between 1.28 pm and 2.20 pm to create a water screen around the gas cloud and cool down the potential ignition points. The inspection authorities for classified facilities were informed via the alert system at around 2.30 pm. Around 2.45 pm, a vertical stream of gas was observed in a pipe wrap at about 8 m from the ground. Around 3.35 pm, a breach was identified on a 500 m long, 4" (101.6 mm) diameter carbon steel pipe carrying liquefied butane and operating under a pressure of 18 to 20 bar. At 3.40 pm, the contents of the line started to be released into the flare network and at just a little before 3.50 pm, the circuit was isolated and the leak reduced. The internal emergency plan was lifted at 4.00 pm. The operator published a press release. The total duration of the leak was estimated to have lasted for a little less than 2 hours and 30 minutes. The operator confirmed that the concentration of the gas had attained only 20% of the LEL.

At the time of the accident, the line in question was filled with liquefied gas but isolated at its ends by valves in closed position. The tube ruptured due to thermal expansion of the liquid at a pressure lower than the set pressure of the valve on the line (48 bar of relative pressure). The examination of the pipe in question revealed an approximately 50 mm X 20 mm longitudinal opening in the upper generator with a diameter of about 30 mm. A significant loss of thickness was observed in the rupture zone. The non-insulated tube showed a generalised corrosion on the entire section. Another rack housing a refrigerated ethylene pipe overhung the wrap containing the defective pipe. The corrosion resulted from the water droplets trickling down from the melting ice surrounding the ethylene pipe situated above the defective pipe.

The investigations carried out by the inspection authorities for classified facilities confirmed the smooth functioning of all gas indicators (from the ones closest to the point of leak to the ones furthest away) gradually reacted between 1.28 pm and 1.30 pm. From a regulatory standpoint, the operator indicated that the pipe was only inspected regularly but not overhauled. The next inspection was planned for 2009.

The steam cracker operated for few days until its programmed shutdown for six weeks.

ARIA 35286 - 09/10/2008 - 38 - LE PONT-DE-CLAIX

49.50 – Pipeline transport

Around 11.30 am, the railway department reported a hydrogen chloride gas leak from a pipeline (MOP 8 bars, NPS 350) connecting two chemical plants due to the emission of fumarole. The surveillance and contingency plan relating to the structure was triggered. The pipeline was depressurised and subsequently drained by the employees.

The leak was caused due to localised external corrosion below the bridge over a stream. During repair operations, paint was directly applied to an iron oxide build-up without polishing the surface. Successive floods and the humidity below the bridge contributed to the corrosion. Water seeped in between the paint and pipe causing deposit corrosion. A specialised company temporarily fitted a watertight collar and a supporting prop onto the structure. The accredited inspection department of the company using the pipeline carried out an inspection on the 9 and 10 of October to ensure the absence of any area conducive to deposit corrosion (humidity, presence of water, retouching). The inspection led to the detection of a high-risk area, more specifically a pipeline passage on the same stream at about 50 m upstream to the previous zone showing corrosion. No additional faults were detected after further checks. The replacement of the pipeline section (20m) was planned during the next shutdown. Following the incident, the operator drafted a press release that was posted online on the company website.

Additional references (detailed sheets):

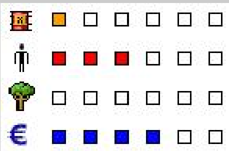
ARIA 7022: The Bhopal tragedy, 2-3/12/1984, Bhopal, India
ARIA 21233: Hydrocarbon leak on a pipeline, 18/09/2001, Lucciana (2B)
ARIA 23182: Rupture of a grain storage cell, 20/09/2002, Vailly-sur-Aisne (02)
ARIA 23368: Rupture of a grain storage cell, 20/10/2002, Jussy (02)
ARIA 30934: Rupture of a crude oil storage tank, 25/10/2008, Kallo, Belgium

Heat insulators

⑭ Explosions in a pharmaceutical plant

ARIA 25337 and 35822 - 13/08/2003 and 08/09/2004 - AUSTRIA - LINZ

21.10 – Manufacture of basic pharmaceutical products



In a chemical plant, 2 explosions occurred in a glyoxylic acid production line followed by a fire. The building in question housed a production unit for intermediate chemicals used in manufacturing antibiotics and crop protection products. The fire-fighters brought the blaze under control in a few minutes. Casualties include 20 cases of injury including a case of serious injury where the person was thrown off the scaffolding by the deflagration. The slight injuries mainly included cuts due to the projection of glass pieces and other debris. A company spokesman confirmed that the building was empty at the time of the accident. Projections were found as far as 150 m. The production line was completely destroyed but the neighbouring buildings only sustained light damage. The internal damage was assessed at 6 M euros. The media reported an operational loss of 15 M euros. Despite the investigations, the real causes of the accident were not known. The summer heat may have triggered a start of fire in a heat-insulated column imbibed with peroxyde (reaction intermediate) and methanol (flammable solvant). The fire may have then spread to the two reaction columns causing them to explode. The new reactors installed are designed to resist explosions. Risk-curtailing measures were also implemented. Nevertheless, a second explosion occurred a year later when the facilities were re-started (ARIA 35822).

In a chemical plant, an explosion occurred when a glyoxylic acid production line using the ozonisation technique was re-started. The facility was destroyed a year ago by an explosion followed by a fire (ARIA 25337).
The internal emergency plan and the external emergency plan were triggered and fire-fighters were brought in from outside. Since the site was implanted in an industrial zone, all neighbouring establishments in the zone were informed on the accident.

The unit, which has been rebuit and reinforced (pressure proof) after the 2003 accident, is severely damaged. Nevertheless, the effects have been contained and no casualties were reported. Production was suspended until further notice. Despite several expertises that cost 400,000 euros, the causes of the accident were not known. The operator modified the process (use of air instead of ozone).

Heat insulators

The first of the two accidents described previously highlights the problems encountered in implementing heat insulating equipment (pipes, cold or warm storage, heat exchangers, etc.) and their regular inspection. Under normal operating conditions, insulating material and its protective sheath make it hard to detect any possible malfunction such as excess heating of an equipment part, leak of reagents, solvents or even the coolant. The risk of corrosion, fire or pollution, sometimes insidious is worsened when the leak has lasted for several days or even months before detection (ARIA 23839).

Several cases of start of fire in a heat insulator following an undetected leak and accumulation of a chemical in the insulating material have been reported (ARIA 20358, 24854, 26369, 26249, 27651, 30623, 31217, 32584, 32691, 33106, 34410, 35114, 35349, etc.). The fire can start upon contact with a hot spot (conditions made conducive by the heat insulator) or electrical equipment: electrical cabinet, heat trace cables, etc. (ARIA 29186, 31217)

During a fire, insulation can also complicate rescue operations by preventing facilities from cooling easily (ARIA 4460, 32163) and making the use of special equipment such as thermal cameras to detect hot spots necessary (ARIA 33713).

A heat insulator can promote (humidity, etc.) or aggravate corrosion due to no or late detection. This mainly concerns pipes (ARIA 6475, 24164, 32347, 32429, 34351, etc.) but also tanks (ARIA 6467, 35282) and columns (ARIA 25337, 26578). Pipes in rack run an additional risk and deserve special care as corrosion in heat –insulated pipes can result in domino effect causing other pipes to corrode (ARIA 35146) through condensation of atmospheric humidity, melting of ice and dripping of water.

The design and implementation of a heat insulator followed by its inspection are crucial for the safety of the facilities after their commissioning. Several accidents have occurred due to defects in equipment design followed by implementation of insulating material and the protective sheath (ARIA 25864, 31718).

Regular inspection of the facilities is vital to detect any possible malfunctioning at the earliest. Heat insulators can be equipped with “inspection windows” to verify the air-tightness of flanges, ensure presence of dedicated leak detection systems, facilitate regular checks, etc.

The accidents whose references are not underlined may be consulted at:

www.aria.developpement-durable.gouv.fr

ARIA 4460 - 27/04/1993 - 84 - SORGUES

20.51 - Manufacture of explosives

On 19 March, a tank glazed with 85% H_2SO_4 ruptured leading to a workshop to close down for five days. Given the waste acid storage autonomy period of four days for production, 3 tank trucks hired in February and not dispatched following a leak in the waste acid tank were reused and three additional tank trucks were hired. Tank truck 2 was half filled with waste acid from the production of dinozebe on 26/02, and completed on 23/03 with waste acid from the production of DNTCBB (dinitro 2-6 tertiobutyl 4 chlorobenzene), a crop protection intermediate. On 27/04, nitrous vapours were emitted from the manhole of tank truck 2. The internal emergency plan was triggered. The insulated tank truck was cooled with water hose nozzles. A water curtain was used to disperse the nitrous vapour cloud that was 30 m high and 180 m long. The tank truck exploded since the situation was aggravated by its insulation and closed vents. An acid aerosol was projected over 135 m, metal debris of 3 kg reached 195 m and 15 m³ of matter was spilt on the ground. Two technicians affected by the accident at the boundary of the site were treated onsite. Despite the projections, three lifeguards located at 25 m remained intact. Ground pollution in the town of OUVEZE was limited and the spill was neutralised with calcium carbonate.

After an enquiry was conducted, it was shown that at room temperature and under adiabatic conditions, dinozebe starts to decompose after 15 days of contact with waste acids from the production of DNCTBB along with the formation of nitrous vapours. There was a slow decomposition reaction between the contents of the tank truck and the trace of dinozebe during the month of storage accompanied by an increase in pressure of the airtight and insulated tank truck. The accident resulted from inadequate cleaning between the two uses and the mixing of incompatible materials that triggered the sudden reaction. Measures were taken for other tank trucks containing the same acids: opening of manholes, cooling devices for tank trucks, etc. The use of temporary mobile storage containers without retention tanks was not allowed. Furthermore no risk assessment studies were carried out on the storage and treatment of waste acids. Material damage was evaluated at 0.36 MF.

ARIA 6475 - 14/03/1980 – THE NETHERLANDS - HENGELO

YY.YY – Activity not known

There was a leak in polyurethane-insulated pipe transporting heated chlorine. The leak occurred due to the decomposition of polyurethane under the influence of heat (60 ℃), and rain and an ambient pH of 2 that resulted in the external corrosion of the pipe.

ARIA 20358 - 10/12/1998 - 13 - MARTIGUES

20.14 - Manufacture of other basic organic chemicals

Ethylene leaking from an approximately 12 cm breach below the cold insulation of a 4-inch pipe used to supply ethylene to a reactor manufacturing dichloroethane ignited and resulted in a fire than lasted 40 minutes.

ARIA 24854 - 01/04/2001 - NETHERLANDS - SITTARD-GELEEN-BORN

20.60 – Manufacture of artificial or synthetic fibres

While re-starting the acrylonitrile units of a synthetic fibre plant, the facilities were flooded with water for 2 hours to test the resistance of equipment. A leak was observed in a steel pipe. Since chlorine was present in the heat insulators covering the pipes, corrosion due to chlorine was immediately suspected to be cause. Several samples were taken and analysed. However, the results excluded the above assumption as the cause of accident. Further investigations revealed that the leak occurred in an area that was often cleaned with sodium hydroxide to remove the frequent polymer deposits. This was confirmed by an expert analysis carried out by a third party. The steel pipe was replaced and as an additional precautionary measure the operator had to test the equipment resistance again by flooding the facilities with water or nitrogen to apply a maximum service pressure for 24 hours under the supervision of the inspection authorities. Since no further leaks were detected, the operator was allowed to re-start the units.

ARIA 26578 - 05/05/1975 - NC -

19.20 – Oil refining

A fire broke out on the distillation tower of an atmospheric distillation unit operating normally in a refinery. The fire appeared on the valve spur of a naphtha stripper. The stripper was heat insulated till the spur. The naphtha leaked out and spread over the heat insulator that caught fire. The accident led to the temporary shutdown of installations and occurred due to the leak caused by a 6 mm crack in the ox-bow of the stripper. Corrosion was responsible for the leak.

ARIA 29186 - 31/03/1966 – UNITED STATES - LAWRENCE

ZZ.ZZ – Unknown origin

The technician of a the nitrogenous solution loading station heard the safety valve open and saw a 2 to 3 m flame surge from the exhauster duct near the pump. An abrupt explosion occurred and the solution gushed out of the tank in huge quantities. The new team had just clocked in 15 min. back after the previous shift which had completed all loading operations, stopped pumps and had left all valves open except the valve in the loading station. An explosion occurred at the elbow of the 10 to 15 cm diameter, ascending steam-insulated and -traced part of the exhauster duct. This was due to the decomposition of the nitrogenous solution upon passing through the holes created by corrosion of the elbow weld into the insulating material made of aluminium. Furthermore, maintaining the steam tracing temperature contributed to the explosion. A similar explosion had occurred in a transfer pipe of the same unit on 25 May 1966 while the steam tracing was not commissioned.

ARIA 31217 - 29/12/2005 - 76 - NOTRE-DAME-DE-GRAVENCHON

19.20 - Oil refining

In an oil de-waxing unit, a pool on fire was detected a little before 6.00 am at the foot of an oil/ammonia cooler that was neutralised the previous day following the detection of a hydrocarbon leak. The fire spread to an area of 50 m² and damaged the electric cabling, piping, neighbouring valves and fittings and four heat exchangers. The internal emergency plan was triggered and the fire-fighters brought the fire under control at 6.18 am. No casualties or pollution were reported. The economic impact, mainly due to the damage caused to the equipment and loss of production due to shutdown of facilities was assessed at 400 k euros. More than 12 hours before the fire, the technician had repaired a leak after draining and emptying hydrocarbons and crystallisable paraffin. The paraffin may have partially solidified in the heat insulator protecting the device thus retaining several hundred litres of solvent. During the previous night, heating with steam would have caused the most volatile substances in the insulator to evaporate. Heat tracing had triggered a wick fire phenomenon that liquefied the set paraffin and released around 2 tonnes of an already ignited mixture. The operator implemented measures to avoid similar accidents from reoccurring.

ARIA 31718 - 07/04/2006 - 74 - TANINGES

10.13 – Preparation of meat products

In a meat packing unit, 200 kg of ammonia (NH_3) leaked at 4.30 pm from a corroded pipe of a refrigeration unit (900 kg of NH_3) cooling two ham and sausage dryers.

[…]

According to [an expert], the corrosion was due to a flaw in the assembly of the heat insulator: the steel of the insulator was not protected by a petrolatum tape or a pitch layer. The corrosion went undetected since the heat insulator showed no signs of damage. The rusted pipes were replaced and the internal action plan was drafted into a written procedure. The operator planned to replace the refrigerant.

ARIA 32347 - 28/08/2006 - 61 - ARGENTAN

10.52 – Manufacture of ice creams and sorbets

In a deep-freezing tunnel of an ice cream manufacturing plant, 40 kg of ammonia (out of a total of 13 tonnes of NH3 in the facility) leaked at 6.30 am from a pipe in the cone production line. The refrigerationist onsite was immediately informed by a technician. At the same time, the workshop's automatic detection system alarm was activated indicating a 300 ppm threshold and was deported to the control room triggering a siren […].

The damaged pipe was covered with polyurethane foam that in turn was protected by a steel coating. Significant external corrosion was detected below the heat insulator. The corrosion could not be detected upon mere visual inspection and was responsible for the rupture of the pipe that operated in rough conditions in a humid atmosphere. This possibility was not taken into account during the safety assessment studies. The emitted NH3 accumulated in the pipe between the closed valve and the point of leak. The operator had already taken steps to prevent corrosion especially when replacing pipes at regular intervals by systematically protecting them with petrolatum tapes to minimise the effects of humidity. A new round of inspection of all pipes in the deep-freezing tunnel was carried out to gradually replace the polyurethane-insulated pipes with petrolatum tape protected pipes as polyurethane speeds up corrosion.

ARIA 33106 - 14/06/2007 - 38 - ROUSSILLON

20.14 - Manufacture of other basic organic chemicals

In the cumene - cumyl hydroperoxide section of a seveso classified chemical facility, a technician on rounds detected a start of fire at 6.00 pm on a 6 bars steam line in the drain. The blaze resulted from the inflammation of a heat insulator imbibed with cumene / cumyl hydroperoxide (highly inflammable chemicals) insulating the pipe. The fire was quickly brought under control using two fire extinguishers and did not impact the rest of the facility.

ARIA 34351 - 16/03/2008 - 44 - DONGES

19.20 - Oil refining

The complete summary of this accident is presented in the sheet entitled “the effects of time on industrial facilities”.

“The examination of the pipe revealed an approximately 16 cm² longitudinal breach caused by corrosion localised under the heat insulator due to the leakage of water from a pipe situated vertically above. The water accumulated below the heat insulator and caused corrosion and then punctured the fuel oil pipe.”

ARIA 35146 - 06/09/2008 - 76 - NOTRE-DAME-DE-GRAVENCHON

20.11 – Manufacture of industrial gases

Around 1.25 pm, a technician detected a strong smell of gas that he identified as propylene and noticed a cloud of fog at the centre of steam cracker without being able to precisely pinpoint the site of the leak. He then went to the control room and sounded the alert. The detection alarms of several gas indicators of the zone were activated on the safety panel […]

Around 3.35 pm, a breach was localised on a 500 m long, 4" (101.6 mm) diameter carbon steel pipe carrying liquefied butane and operating under a pressure of 18 to 20 bar. At 3.40 pm, the contents of the line started to be released into the flare network and at just a little before 3.50 pm, the circuit was isolated and the leak reduced. The internal emergency plan was lifted at 4.00 pm. The operator published a press release. The total duration of the leak was estimated to have lasted for a little less than 2 hours and 30 minutes. The operator confirmed that the concentration of the gas had attained 20% of the LEL […]

The examination of the pipe in question revealed an approximately 50 mm X 20 mm longitudinal opening in the upper generator with a diameter of about 30 mm. A significant loss of thickness was observed in the rupture zone. The non-insulated tube showed a generalised corrosion on the entire section.

Another rack housing a refrigerated ethylene pipe overhung the wrap containing the defective pipe. The corrosion resulted from the water droplets trickling down from the melting ice surrounding the ethylene pipe situated above the defective pipe.

[…] the operator indicated that the pipe was only inspected regularly but not overhauled. The next inspection was planned for 2009. […]

ARIA 35349 - 31/10/2008 - 13 - CHATEAUNEUF-LES-MARTIGUES

19.20 - Oil refining

At 2.45 pm, a fire broke out in the heat insulator of a steam line in a pipe network inside a retention system without any storage tank. Following heavy rains, the heat insulator was imbibed with heavy hydrocarbons brought by the rain water.

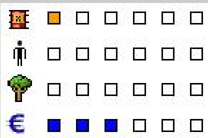
The safety department took immediate action and put out the fire that released a cloud of smoke after several minutes. End of alert was sounded at 3.00 pm. The operator drafted a press release the very day.

Communicating under difficult circumstances

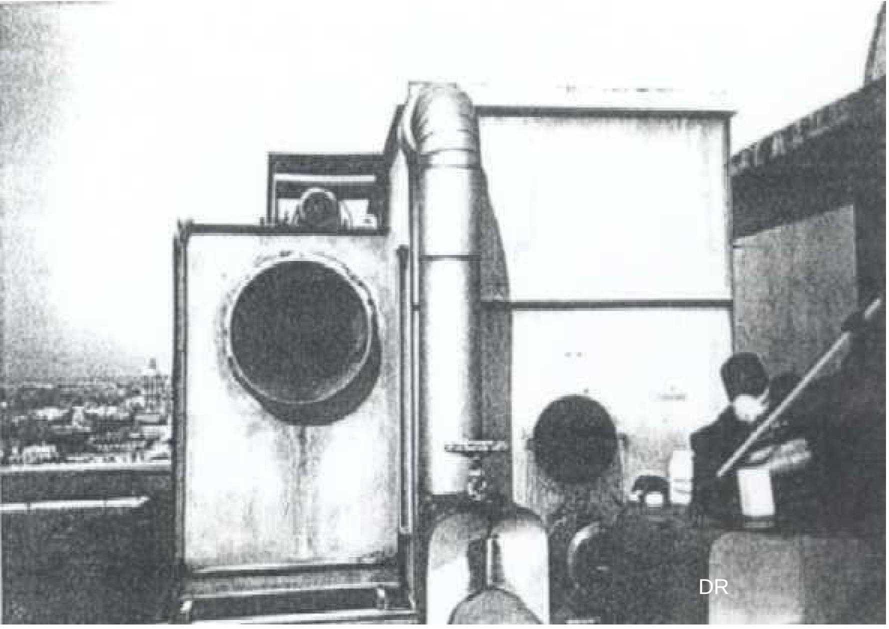
⑮ Soot from fire

ARIA 33299 - 30/07/2007 - 42 - RENAISON

10.72 – Manufacture of biscuits, rusk and hard baked goods



A fire broke out at around 2.00 am in a 10,000 m² cake and confectionery manufacturing plant. The video surveillance company informed the maintenance manager. Around hundred fire-fighters arrived onsite with 27 fire engines. The fire-fighters cut off the gas and electricity supply, stopped traffic in the D9 by-road to pump water in a pond and brought the blaze under control at 6.00 am. Fire-fighters stayed back to monitor for any possible restart of fire. The mayor and staff from the press were on site. The retention tank and the pre-treatment station were full and thus could not hold the 200 m³/h of fire water. This flowed outside the site into a canal receiving rainwater from the site that drained into the OUDAN River. The rescue services set up a straw-bale dam. 90% of the plant was destroyed especially due to the presence of significant amounts of combustible material (sugar, flour, carton, etc.). The cooling units, functioning with R404a (mix of fluoroethanes) were impacted releasing hydrofluoric acid but the stocks (silos) of 60 m³ of sugar and 65 m³ of flour along with the hydrocarbon tanks and the site's transformer remained intact. No victims were reported but the accident resulted in the technical unemployment of 120 people. On 01/08, the public water body management and surveillance authority detected no immediate impact on the canal. Appropriate resources will be deployed to treat the debris. The soot and other material generated by the fire fell onto the neighbouring gardens and fields in a 3 km wide and 6 to 10 km long lane causing worry to the residents. The inspection authorities for classified facilities ordered the operator to carry out quality surveillance measurements in the zone south-east to the site likely to the impacted (total hydrocarbons, PAH, halogenated VOC, heavy metals, dioxin ...). The results of the analysis of the soil and plants for human and animal consumption indicated levels below the threshold values but the canal water and sediments were contaminated by dioxin, PAH and heavy metals (Arsenic, lead and Zn). The results of the analysis carried out in January 2008 showed that the pollution of the water body, due to the fire of the plant, was cleared and that some of the pollutants detected previously are part of the background of the environment. The operator drafted a plan to assess the pollution impact on sediments and assess the environmental quality around the production site. The safety studies of the site did take into account a generalised fire in the site and planned measures to promptly control the fire which was not the case (15 h to extinguish the fire). The factory is rebuilt at the same place 18 months later at a cost of 15 Meuros: the establishment is equipped with a fire detection, sprinklers and a much bigger retention for firewater (840 m³). A short circuit in an electrical cabinet (installed in 1980) has triggered the fire.



⑯ Mercury pollution

ARIA 35840 – 01/22/2008 - BELGIUM - ANDERLECHT

24.54 – Smelting of other non ferrous metals

On the 21 to 22/01 and 24 to 25/01 nights, the air monitoring stations continuously recorded mercury (Hg) concentrations as high as 1 micro g/m³, i.e. 1,000 times greater than the WHO threshold for chronic exposure.

Laborious research involving significant human and material resources including a mobile laboratory helped identify the source of pollution: the incinerator of a metal foundry producing lead bullions from old batteries. A concentration of 9,300 mg/m³ of mercury was measured outside the incinerator's stack that was stopped shortly after.

An enquiry was conducted. The operator was unaware of the origin of pollution since the company did not recycle mercury. The environmental police sealed the batches of waste in question (batteries from France) to check for any possible mercury pollution. The waste was then treated using an adapted process. A specialised company carried out a land pollution survey around the plant to assess the impact of pollution on health and environment. The environmental departments feared a possible pollution of some kitchen garden areas and the consequential risk to the food chain.

Besides the fact that the awareness resulting from the incident led professionals in the battery recycling sector to raise questions on securing their supplies, concrete preventive measures were taken in the company during the various stages of its processes to avoid such accidental spills from reoccurring: increasing accountability among suppliers, checking incoming material with a manual mercury detector, installing a flue gas scrubbing device using activated charcoal, checking the efficiency of gas scrubbing by constantly monitoring the mercury level in the flue, drafting procedures on taking action and informing authorities if atmospheric emission standards are crossed, etc. There measures were made part of the new operating license of the company that stipulated even more stringent emission standards. The company was to be heavily fined by the administrative authorities.

Communicating under difficult circumstances

"Laborious research" involving significant human and material resources was required to identify the origin of the mercury pollution peaks detected in Brussels in January 2008.

Any symptomatic event provides the occasion to carryout investigations to assess the potential risks and stakes. As in the case of the 2nd accident presented (soot from fire), identifying the nature of the materials or elements involved (ARIA 8319, 9729, 13666, 20493…) may require considerable time and energy and even acquiring new knowledge. The discovery of the Legionella bacteria in 1977 called into question all previously propounded theories (ARIA 26108).

Several obstacles may be encountered during the research:

- Even though the persistent, bioaccumulable and poorly biodegradable nature of some substances (PCB, PCT, PCP, lindane, dioxins and other organochloride compounds, metals, radioactive material, etc.) reveals chronic or accidental pollution (ARIA 20493, 29977, 35035, 35874, etc.), it may be hard to identify the source of the detected anomalies due to the historical precedence of the events (ARIA 2257, 8984, etc.)
- Investigations are complicated by the often insufficient knowledge of the locale concentrations (average values, etc.) and the potential sources adding to the pollution. The diffuse risks, as well as the multitude of facilities and equipment in question also widen the number of causes. Legionellosis once again is a rather good example: ARIA 18511, 21993, 23125, 23194, 23246, 25551, 26002, 26106, 26113, 26118, 29883, etc.
- Atmospheric pollution of unknown or poorly identified origin including odours also illustrates this type of problem: ARIA 9729, 20310, 26008, 26438, 27109, etc. However, water, soil, water tables, "confined" environments that are theoretically easier to understand, may also fall prey to pollution of unknown origin especially following a separation network failure (rain water / waste water), interconnection of headers, etc. (ARIA 2257, 8319, 8984, 13029, 13666, 21012, 22138, 24994, 25676, 28171, 28805, 28905, 30261, 32305, 33672, 33712, 34761, etc.). The sudden, discontinuous or random emission of waste can also make investigations harder (ARIA 2257, etc.)
- The need to carry out measurements on cultivations, food products or samples and run biological tests on employees, rescue workers, investigators, reporters or the adjoining population can worsen the fears and concerns of the society and authorities (ARIA 18511, 20493…).

Despite the hardships involved in describing accident situations and identifying the possible effects, it is up to those who hold information, especially authorities, to take the initiative of bringing critical situations to the notice of the public. As far as possible, reference values and the initial risk mitigation measures taken or planned must be stated alongside the description of anomalies so that the effected population can form an opinion on the possible health or environmental risks and take the necessary precautions if required (ARIA 29977, 30269, 35035, 35874, etc.).

Concern and partial understanding of a situation, such as the "suspense" in carrying out investigations must not be a stumbling block in sharing even incomplete or adverse information likely to draw public attention. The official information campaign held in the beginning can be gradually supplemented with others as the investigation progresses. Incidentally, since measuring techniques have become very sophisticated and health and environmental checks are becoming increasingly stringent, the anomalies involving persistent substances are more often detected by monitoring networks: deterioration of food products, contamination of water tables, atmospheric pollution (ARIA 35035, etc.).

The absence or insufficient official communication on the observed anomalies can only lead to questions, worries, standpoints based on subjective factors and even rumours thus putting authorities in an uncomfortable position of having to justify. It is even more important to promptly communicate in critical situations. Modern information and communication technologies make it possible for everyone to instantaneously communicate information that may be true or false.

Otherwise, the bearer of adverse information will be suspected of concealing information in the event of not taking the initiative to share it promptly (ARIA 23839, etc.).

It is advisable to bear in mind the above points to optimally communicate in difficult circumstances in a modest way without neither evading the encountered problems nor reassuring the public at all cost. More than technical information, experience shows that there is a high expectation from the pubic to know the truth.

Additional references (detailed sheets):

- ARIA 20493 Vénizel 2001 / Transformer fire containing PCB
- ARIA 23839 Chalampe 2002 / Long lasting cyclohexane leak
- ARIA 26002 Harnes 2003 / Outbreak of legionellosis in HARNES.

The accidents whose references are not underlined may be consulted at:

www.aria.developpement-durable.gouv.fr

ARIA 2257 - 04/08/1990 - 76 - PETIT-COURONNE
19.20 – Oil refining
In a refinery, an underground pipeline carrying premium grade unleaded petrol between a tank and an oil wharf had been leaking since at least 1985. This leak polluted the ground water and caused the use of drinking water catchment to be discontinued. However, gas emissions spreading though the city's sewage system led to an explosion in a detached house located 2 km away after the mixture was ignited upon re-starting the water heater in the residence.
After 20 days, investigations revealed a hole of a few mm^2 wide hole in the corroded pipeline. Over 15,000 m³ of hydrocarbons were lost and over 13,000 m³ were pumped into the water table. The operator compensated the aggrieved third parties by purchasing the destroyed detached house and indemnifying the water supplier and the local authorities. The total cost of operations crossed 50 MF.

ARIA 8319 - 20/07/1995 - ITALY - MONCALIERI
ZZ.ZZ – Unknown origin
A river was polluted by a toxic substance: oily brown stains on the surface, thousand of fishes killed, etc. Three accident scenarios were thought of to explain the events: industrial production waste, release of buried waste (300 broken barrels of toxic products upstream to the river) or deliberate dumping of waste into the river. The river water and the fishes were studied to identify the substances in question.

ARIA 8984 - 30/05/1996 - 95 - LOUVRES
ZZ.ZZ - Unknown origin
During the annual examination of drinking water, an abnormal quantity of cyanide was detected in the distribution network supplying four villages (35,000 people). The polluted water table was used by seven water catchments. One of them was closed following the detection of 250 µg/l (max. authorised concentration - 50 µg/l) of cyanide. The source of this pollution was unknown (industrial site, uncontrolled dumping, etc.). If the situation worsened, it was planned to interconnect the water supply network of the village to the network of adjoining villages. The water table and supplied water were analysed on a daily basis. A legal enquiry was conducted.

ARIA 13666 - 18/08/1998 - 29 - CHATEAUNEUF-DU-FAOU
ZZ.ZZ - Unknown origin
The waters of the NANTES - BREST canal were polluted killing thousands of fishes over an area of 15 km between CARHAIX and CHÂTEAUNEUF-DU-FAOU. The several tests run on the canal waters and effected fauna did not reveal the nature and source of the pollution. As a safety measures, the inhabitants in question were advised against drinking supplied water momentarily. Water was released (700 l/s) to dilute the pollution. A pumping station stopped talking water samples for a few days. Dams were installed to recover dead fish.

ARIA 18511 - 04/08/2000 - UKRAINE - CHAUSOVO
ZZ.ZZ - Unknown origin
Children from 3 southern Ukraine villages (CHAUSOVO, MICHURINO and PIDGIRYE) were hospitalised following pollution of soil by nitrates and nitrites causing redness, sleepiness, loss of appetite and vision disorder. The children of a 4th village (BOLESLAVCHYK) may have been evacuated the same way. 330 people including 170 children were hospitalised in three weeks. The governor of Ukraine set up a special enquiry committee to identify the reasons behind the events.

ARIA 20493 - 18/06/2001 - 02 - VENIZEL
17.12 – Paper and carton manufacturing
A fire broke out around 2:50 am in an electrical utility room at a paper mill. Engulfed in the flames, four transformers emptied entirely and a fifth halfway, dispersing a dielectric containing PCB. A prefectural order motivated by a proposal from the inspection authorities for classified facilities was issued given the risk of contamination by dioxins and furans generated during the fire. The order commissioned investigations to determine the extent of contamination and shut down the facility. The re-commissioning was subject to the operator producing supporting documents and authorisations provided for in the prefectural order.
A total of 96 individuals present at the time of the accident (including fire-fighters, employees, journalists and neighbours) had to undergo epidemiological supervision for a full year. The trajectory of smoke led to delimiting a 2.5-km cone-shaped zone for future monitoring and a ban on consuming plant products. About one hundred samples of soot, building materials, soils, water and plants revealed the presence of dioxins and furans at higher concentrations near the site of emission.
A prefectural order dated 4 July 2001 set forth conditions for the partial and gradual re-commissioning of the facilities (stripping of soil and cleaning) and imposed identification and closure of all onsite PCB facilities within a year.
Taking into account the 3 series of analysis on plants, soil, water that revealed PCB and dioxin levels within the daily admissible limits, the ban on exterior land was lifted 25 days later. The quantity of PCB lost equalled approximately 600 kg (of the 2,800 kg initially included), and the quantity of dioxins emitted was 13 kg. The building that caught fire was completely destroyed, with damages estimated at 15.2 million euros. The fire may have resulted from a short-circuit or the poor condition of an electrical component. The "transformer fire" scenario had not been investigated in the safety study.
In all, 26 transformers containing PCB were gradually removed from the site until August 2002. Despite the initiatives taken by the inspection authorities for several years, the removal of transformers damaged by the fire and the stripped soil was still being finalised in summer 2008
The management of the accident also highlighted the need of close consultation between the various departments of the national authorities, a real-time communication for the various players involved, as well as follows up of the actions taken by the operator.

ARIA 21993 - 08/08/1999 - 75 - PARIS
ZZ.ZZ - Unknown origin
In the 15th district in Paris, 8 cases of group contamination with legionellosis were detected on 1 September while the first symptoms were identified as early as 8 August. One patient died. The media pressure rose rapidly. The results of the epidemiological investigation commissioned on 1 September excluded hot water in favour of an environmental contaminating bacterial strain possibly spread by cooling towers.
Alongside the epidemiological investigation, an environmental investigation was launched in the areas visited by the patients within a radius of 500 m: 20 establishments were identified in the 15th district. The gathered information helped identify 6 high-risk sites including one visited by the deceased person who was working in a terrace. The first analysis campaign was launched on 8 September. To detect the possible presence of legionella bacteria, samples were taken from the 20 cooling towers in question: 4 of the 6 sites housed at least one contaminated tower. Strains identical to those infecting the patients were found on 1 site housing 8 cooling towers for 4 cooling circuits. Two of these cooling towers showed bacterial contamination between 1,000 and 100,000 CFU/l. The investigation revealed that the tower dilution system had broken down in the end of July. The facilities were obsolete (pipes not in use, scale formation) and a concentration effect was likely.
After inspecting the facility, the operator made several changes (removal of pipes not in use, etc.). A prefectural order dated 15 September ordered the cooling towers at "risk" to be drained and disinfected. A preventive biocidal treatment was administered and the consumption of water and the physico-chemical properties monitored. The inspection department launched a campaign to monitor check the classified facilities in the perimeter of contamination. This accident showed that training and sharing information with

operators was virtually non-existent and the liabilities associated with the cooling towers (circuit design, scale formation, air inlets, random water treatment procedures, difficult access to the cooling towers) were rather hard to manage. The inspection was vital in some cases and so was a detailed visit to facilities at risk. A maintenance manual had to be drafted to keep record of the failures effecting facilities and the actions taken by the operator.

ARIA 23839 - 17/12/2002 - 68 - CHALAMPE

20.14 – Manufacture of other basic organic chemicals

During efforts since the previous day to locate the source of a pressure drop on the cyclohexane supply line of an olone production facility, a leak of this substance was discovered at a chemical site. The substance, used in large quantities, is of relatively low toxicity, although it a pollutant and flammable.

Stored in a 10,000 m³ reservoir, the cyclohexane is supplied to the olone and adipontrile (ADN) facilities by a partly common pipeline. Maintained at the proper temperature by a steam system, the cyclohexane is transferred at 20℃ and at 2 to 3 bar through lagged overhead or underground piping. With an output ratio of 266:1, 2 pipes, 100 and 40 mm, provide a continuous supply to the olone shop and a discontinuous supply to the ADN shop.

According to the operator, the leak occurred from the rupture of the ADN shop's 40 mm pipe due to the dilation of liquid cyclohexane in the overhead part of the pipe between two blockages of crystallized cyclohexane. A malfunction of the pipe heating device (T < 6.5℃) led to the formation of blockages, with the cyclohexane then reliquifying primarily in the section the most exposed to the outside heating. As the piping was not yet equipped with a device for rapid leak detection, it took 30 hours to determine the cause of the pressure anomaly. The operator initially estimated the leak at just a few m³ of cyclohexane, then between 850 and 1,200 t in the following weeks, the vast majority had migrated into the ground. A few days later, core samples taken at a depth of 13 m (the depth of the water table) showed the presence of a layer of cyclohexane localized near the site of the leak; lowering of the water table by one of the wells of the site's hydraulic security barrier would have limited the spread of the pollution. Analyses of the water table off site showed no trace of cyclohexane above the drinkability threshold.

On July 2, 2003, 420 t of cyclohexane were pumped from the water table and 16 t extracted from the ground through venting techniques... In July 2004, 590 t of cyclohexane had been recovered, although cleanup operations had slowed considerably since the first of the year, with the quantities of cyclohexane recovered stabilising around ten tonnes per month. Consequently, a Prefectural order was issued July 28, 2004 to request that risk analysis be conducted within the scope of a remedial plan.

ARIA 26002 - 28/11/2003 - 62 - HARNES

20.14 - Manufacture of other basic organic chemicals

On November 28, 2003, two cases of Legionnaire's Disease were recorded, the first symptoms of which dated back to the beginning of November. The dates of outbreak of the pathology, which were then staggered over time, revealed two distinct waves of contamination with a total of 86 individuals contaminated, aged between 32 and 92 (of whom 18 died). These cases all broke out within a radius of slightly over 10 km around the city of Lens. The DDASS (local Sanitary and Social Affairs Office) conducted environmental investigations at the homes of patients and within several facilities open to the public. At the request of the DRIRE (Regional Agency for the Environment, Research and Industry), all facilities operating cooling towers within the designated zone were asked to adopt measures to identify the eventual presence of legionella and clean their circuits.

On October 15, the operator of a chemical installation specialised in alcohols and fatty acids extracted samples whose results revealed a concentration of legionella at a level of 730,000 CFU units/litre. Following a shock treatment using biocides, analyses 15 days later yielded a concentration of less than 100 CFU/litre. On November 20, another inspection announced that the level of 600,000 CFU/litre had been reached. In light of these results, the chemical plant's cooling towers were ordered to be shut down on November 29. As of December 3, the tower circuits were drained and cleaned. Operations resumed on December 22, and a prefectural decree was issued January 2, 2004 mandating the operator to halt all plant activity once again due to the appearance of a second epidemic wave.

At the same time, the Prefect commissioned the DRIRE Agency to extend its investigations, notably by inventorying all cooling towers within the neighbouring 53 towns and imposed the shutdown of several installations (automobile washing stations, food processing activities, refrigerated warehousing, etc.), causing layoffs to hundreds of workers for several days. Even though a similarity was detected between the strains extracted from 23 of the patients and those present in the suspected cooling tower at the petrochemical plant, other sources of contamination could not be ruled out. High legionella counts in the lagoons of this same plant necessitated turning off aerators on January 20. This site's revenue loss would amount to several millions of Euros, corresponding to a production downtime of 14 weeks. A prefectural order authorising reactivation of the towers was issued on March 19, 2004, yet the plant would never operate again.

ARIA 26108 - 01/07/1976 – UNITED STATES - PHILADELPHIA

55.10 – Hotels and similar accommodation

During an American Legion veteran convention in a hotel in Philadelphia, over 200 participants developed a form of pneumonia and had to be hospitalised. This lung disease accompanied by high fever did not respond to treatment with standard antibiotics. Food poisoning was thought to be a reason even though the real reason behind the disease was still unknown. Among the veterans, 29 deaths were reported that created an unprecedented wave of panic. 34 people including people passing by contracted this disease. It was only after six long months of investigation that the 'Center for Disease Control' (CDC) Atlanta discovered in January 1977 a new bacterial species (Legionella) responsible for this disease named "Legionnaires' disease" given the circumstances.

ARIA 27109 - 16/05/2004 - 38 - GRENOBLE

ZZ.ZZ - Unknown origin

At 7.30 am, around 100 people took ill in a district of the French city of Grenoble due to a strong odour with a pungent taste and causing irritation to the eyes. The police, fire-fighters and a representative of a chemical platform who were alerted several times carried out reconnaissance operations. The colorimetric analysis (chlorine) carried out on the air samples yielded no results. The odour disappeared late in the morning. No chemical leak was reported and the people were not asked to stay indoors or evacuate the district.

ARIA 29977 - 01/01/2005 - 45 - GIEN

38.11 - Collection of non-hazardous wastes

As part of the mandatory annual analysis of atmospheric emissions, the operator of a household waste incineration plant received on October 8, 2004 the analyses of samples extracted during the month of August, showing: considerable excess of CO (312 and 664 mg/m³ vs. a threshold of 100 mg/m³) on two processing lines (l1 and l2) and in HCl on the l2 line (571 mg/m³ vs. threshold of 50 mg/m³), along with high values of dioxins (29 and 221 ng/m³) on the two lines. Informed of these results on November 8, the local DRIRE Environmental Agency proposed issuing a formal notice to impose compliance with regulatory thresholds in addition to a monthly monitoring campaign instead of annual tests (January 2005 directives), including: tracking of atmospheric emissions and impact of dioxins within a 5-km radius (analyses conducted on milk from adjacent dairy farms, atmospheric fallout).

On January 21, the DRIRE Office received the cross-check analyses of discharges conducted during December: no threshold excess on the l1 line, marked excesses of both CO and HCl (513 and 183 mg/m^3) on l2, very high dioxin contents on both lines (21 and 308 ng/m^3). On the same day, the Agency requested closing l2 altogether (to take effect on January 24), and ultimately suspending this line (order issued on March 16 upon recommendation of the local Hygiene Office). On February 23, the samples taken in January confirmed the facility's malfunctions and the need to shut l2 down: 1,875 mg/m^3 of CO and 680 ng/m^3 of dioxins above the previous findings.
The enhanced atmospheric emissions monitoring programme indicated a return to normal operating conditions on the l1 line. Monitoring was extended out of precaution and oriented towards ensuring food safety, i.e.: dioxin levels found in the soils, plants, eggs, vegetables, grazing lands and fodder. According to the experts (AFSSA, INVS), these results did not reveal any abnormal level of contamination among the various media nor an exaggerated potential health risk for neighbouring populations: in particular, the rate of dioxins in storm water collector pipes was observed to be low in comparison with typical values, the amounts found in milk were compliant with sanitary standards (which equals 3 pg I-TEQ/g of fat, i.e. the value above which milk is recalled from stores), and high concentrations in eggs from family farms attributable, following a field investigation, to local practices. According to the facility operator, an inadequate level of waste preparation (formation of "clusters", accumulation of iron wires) would explain the poor combustion (resulting in the formation of CO and dioxins). The fluidised bed would have gradually deteriorated. The malfunction of smoke exhaust treatment using milk of lime would explain the HCl contents.
Works intended to bring operations into compliance and optimise both incinerator furnaces were undertaken. The plant would start up again 3 years hence (January 2008), and at that time the pollutant discharge measures were compliant with regulatory standards.

ARIA 32305 - 02/10/2006 - BULGARIA - NC
ZZ.ZZ - Unknown origin
An oil slick of unknown origin drifted into the DANUBE river polluting over 100 km of the Bulgarian part of the river according to the Bulgarian authorities. A nuclear power plant using the waters of the river for its cooling system took preventive measures by implementing oil booms and through additional filtration. The Bulgarian authorities made an official request to the authorities of the 12 riparian countries to identify and treat the pollution source.

ARIA 35035 - 22/08/2008 - 42 - SAINT-CYPRIEN
38.32 – Recovery of sorted waste
A fire broke out at around 4.00 am in a 2 000 m² wood storage area of a wooden pallet recycling plant. The security guard of the site living just opposite the wood storage area spotted the fire and informed the emergency services. Several water nozzles were installed once the fire-fighters arrived on site. A thick could of smoke was seen above the village.
The inspection authorities for classified facilities arrived on site at around 1.30 pm and observed that the wood stock was likely to have been soiled or treated with chemicals and the volume of the wood stored was greater than the quantity allowed by the authorised operating regime. The operator admitted having forgotten to inform the prefecture or the inspection authorities. An emergency order recommending the analysis of underground water in the site and in the neighbouring farming areas was issued.
The origin of the fire was unknown. It may have started in a mill grinder. The gendarmerie (French military police) carried out an inquiry to determine the causes of the accident.
On Wednesday the 3 September, the smouldering was kindled by a gust of wind. The fire-fighters were called in once again. The assistant prefect visited the premises. Three orders were issued by the prefect of the Loire region: suspension of activities, emergency, cleaning and waste disposal measures and formal notification to remedy all administrative discrepancies in the company. It took three month for the fire-fighters to bring the fire under control once and for all. Precautionary measures on human and animal food were taken within a 1 kilometre radius of the plant in question. PCB contamination was detected in Saint Cyprien causing a farm with 85 cows to be isolated.
On 24 December, an emergency order was issued by the prefect recommending a new analysis of the underground and surface water, soil, and plants as well cleaning of the pits.
On 30 January, several prefectural orders were issued banning the sale and consumption of all animal products within a radius of 1 km. Seven farms were isolated a ban on feeding animals with food produced on the lands within the 1 km radius of the plant was put in place.

ARIA 35874 - 22/08/2008 - BELGIUM - FLEURUS
21.20 – Manufacture of pharmaceutical preparations
Iodine 131 leaked during the transfer of a liquid effluent between 2 tanks in a medical laboratory of a institute specialising in the production of therapeutic radioactive elements. The plant is the world's second largest producer of radioactive elements marketed in liquid form to be used in medical imaging and cancer treatment. On Monday, the staff of the institute observed an abnormally high isotope content in an evacuation stack following a failure of the plant's filtration system. The AFCN (Belgian federal agency for nuclear safety) that was alerted to the accident also informed the ASN (corresponding French body for nuclear control)
The accident was initially said to be consequence free, and then further to the analysis of plant samples in the vicinity, the authorities warned the people a few days later of possible contamination. To this effect, the police communicated messages in the roads using loudspeakers asking the 20,000 inhabitants of the district to refrain from consuming fruit and vegetables from the gardens, rain water and milk from neighbouring farms. These measures concern several villages within a radius 5 km from the point of release. The radius was reduced to 3 km in the end of August when the air and water samples were free of radioactive substances. To reassure the masses, several hundred children underwent a salivary gland test the following week.
The conducted enquiry assessed 45 GBq of emissions released in 4 days, i.e. the dosage absorbed at one go by 12 patients suffering from thyroid cancer. Once in the body, 30% of the iodine 131 settles on the thyroid gland (given the short life time of iodine 131). The health impact is therefore considered to be extremely low. The accident was however rated 3 out of the 7 level International Nuclear Event Scale.
The accident is believed to have resulted from a handling error. Failure of the computed managing the alarms was also mentioned. The technician on duty thought it to be a "filter problem" and tool no special measures, allowing the production cycle to run for over 24 hours. According to the press, both the French and Belgian nuclear safety agencies had identified defects in the laboratory's safety system during a joint audit carried out in November 2007.

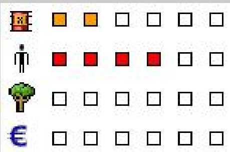
Mixing of incompatible products

DR

⑰ Accidental generation of chlorine in a company trading in chemicals

ARIA 35830 – 05/10/2007 – GERMANY – FRANKFURT AM MAIN

46.75 – Wholesale of chemicals



A cloud of chlorine gas was accidentally generated around 10.30 am while transferring hydrochloric acid (HCl) into a tank containing sodium hypochlorite (NaClO or liquid bleach) in a chemical wholesale company.

The accident happened during a period of rebuilding of the unit; the filling station and the delivery station were in the process of being renewed. At the delivery station for tankers there only one connection for all chemicals but $FeCl_3$. A pump transports the fluids via pipe to a connection battery / filling station for drums. At the battery, a worker connects the pipe, by using a hose, to the right tank. The technician chose the wrong tank at this point. Realizing his mistake, he stopped the transfer operation thus limiting the quantity of chlorine released to 200 kg. The employee was severely poisoned and died a month later.

The police stopped traffic in the industrial area and the residents within a perimeter of 200 metres were required to stay indoors for 2 hours. 54 people were treated by around 120 fire-fighters.

Further to this accident, the unit is rearranged:

- The delivery station for roadtankers was equipped with a separate filling pipe for hypochlorite. The adapter was equipped with left hand threads (mistake-proofing?).
- All adapters of the storage unit were locked off and keys will be released after analysis by the laboratory personnel.
- All connections were clearly labelled.
- The hypochlorite pipe is monitored by a pH-electrode.

Mixing of incompatible products

This tragic accident in a non-SEVESO German facility illustrates the frequent risk related to transferring chemicals between fixed or mobile tanks during both filling and emptying of reactors or any other storage containers used in the industry. This risk concerns accidental mixing of incompatible products (ARIA 10086, 10851, 15375, 14377, 17921, 17941, etc.).

This risk is ever more insidious as the mixtures generally involve so widely-used “standard” substances such as sodium hydroxide, liquid bleach, acids (hydrochloric, sulphuric, phosphoric, nitric, etc.) that the technicians “forget” or “underestimate” the potential danger. The risk of mixing incompatible products resulting in chemical (acid/base, ferric chloride/bleach, etc.) or physical reactions (exothermal dilution: concentrated acid/water, acid/acid, etc.) accidentally or due to lack of knowledge of the physico-chemical properties of the products involved is consequently increased.

The accidental mixing may suddenly result in the production of significant quantities of toxic or inflammable gaseous reactants or corrosive projections and even lead to the damage or destruction of the container due to either a significant rise of temperature of the liquid or accelerated corrosion.

Several accidents recorded in the ARIA database underline the importance of certain factors whose role is crucial in preventing such accidents:

- A sound risk analysis underlying such operations to identify a maximum number of triggering events and reduce their occurrence (11664, 27555, 29036, etc.).
- Appropriate ergonomics of installations with storage of incompatible products in distinct tanks, including their retention tanks (ARIA 6004, 15976), sufficiently spaced apart and as far as possible without common pipes (supply, gas phase return, etc.).
- Clear labelling, ID colour code on transfer hoses and related storage containers, mistake-proofing for filling devices (manifold, etc.) end pieces, etc. The risk of errors is increased in the case of unequipped facilities (ARIA 10851, 22217, 27555, 29036, etc.).
- Specific training of staff, employees of company or subcontractors performing operations (ARIA 167, 220, 21984, 27555, 32131, 32582, etc.). Regular reminders on guidelines and possible incompatibility between products or products and material maintain the awareness to risk underlying these operations deemed “simple” but that always require a certain degree of caution and care. Since risk prevention devices are relatively limited, the organisational abilities of the company mainly form the basis of measures for reducing risks.
- In addition to the deliveryman, the presence during the entire operation of at least one other person trained in the “receiving” company, who can guarantee the safety of facilities, effective transmission of information and smooth transfer, is strongly desired. Accidents occur when a deliveryman either on his own or just temporarily accompanied by a technician makes a mistake in identifying the tank or makes a wrong connection (ARIA 220, 22217, 27511, 27555, 29036, 30614, 32582, etc.).

Moreover, even though the kinetics of reactions involving incompatible products is generally very fast, some of them may be slow enough, at least in the initial phase, to go unnoticed or unreported at the time of the moment. This consequently results in accidents deferred in time (ARIA 4460, 34431, etc.). It is this advisable to report all errors or accidental mixing even if they seem consequence free at that particular moment so that the potential risk of the situation can be analysed and appropriate measures taken at the right time if needed.

Lastly, for such type of relatively frequent accidents, whose prevention mainly depends on organisational measures, a global approach is ever more called for. Protective barriers formed by risk-reducing technical devices (valves, vents, personal protective equipment, etc.) or human intervention (emergency measures such as stop of transfers, alerts, neutralising accidental mixtures if needed, etc.) as well as limiting consequences by protecting people (confinement, evacuation, etc.) must be planned and regularly tested.

The accidents whose references are not underlined may be consulted at:

www.aria.developpement-durable.gouv.fr

ARIA 167 - 17/07/1989 - 58 - NEVERS

29.32 – Manufacture of other automobile equipment parts

While transferring sulphuric acid using compressed air, the driver cum deliveryman connected a hose to a pipe connected to a tank containing sodium hypochlorite. After the transfer of 15 litres of acid, a site employee, supervising the experienced driver delivering in the plant for the first time, heard an explosion and closed the compressed air valve immediately. The vent of the tank was ripped off. The chlorine released in the workshop poisoned the driver and 28 other employees (one case of serious intoxication) who were hospitalised. The accident occurred due to the presence of four similar pipes, transfer mode (air pressure --> inertia, etc.) and poor risk-awareness training of the driver cum delivery man. The delivery of products to the site was re-examined.

ARIA 220 - 12/07/1991 - JAPAN - FUJI-SHI

17.1 – Manufacture of paper pulp, paper and carton

A tanker truck carrying 2 tonnes of aluminium chloride was emptied into a tank containing 11 tonnes of sodium hypochlorite. The driver came for delivery outside working hours and was misguided by the security guards. The mixture caused chlorine to be released. The emissions poisoned 46 employees, six residents and 58 employees of neighbouring facilities who were taken to 11 hospitals. 230 families were evacuated for 7 hours. The chlorine cloud impacted a surface of 4 km².

ARIA 4460 - 27/04/1993 - 84 - SORGUES

20.51 – Manufacture of explosives

On 19 March, a tank glazed with 85% H2SO4 ruptured leading a workshop to close down for five days. Given the waste acid storage autonomy period of four days for production, 3 tank trucks hired in February and not dispatched following a leak in the waste acid tank were reused and three additional tank trucks were hired. Tank truck 2 was half filled with waste acid from the production of dinozebe on 26/02, and completed on 23/03 with waste acid from the production of DNTCBB (dinitro 2-6 tertiobutyl 4 chlorobenzene), a crop protection intermediate. On 27/04, nitrous vapours were emitted from the manhole of tank truck 2. The internal emergency plan was triggered. The insulated tank truck was cooled with water hose nozzles. A water curtain was used to disperse the nitrous vapour cloud that was 30 m high and 180 m long. The tank truck exploded since the situation was aggravated by its insulation and closed vents. An acid aerosol was projected over 135 m, metal debris of 3 kg reached 195 m and 15 m³ of matter was spilt on the ground. Two technicians affected by the accident at the boundary of the site were treated onsite. Despite the projections, three lifeguards located at 25 m remained intact. Ground pollution in the town of OUVEZE was limited and the spill was neutralised with calcium carbonate.

After an enquiry was conducted, it was shown that at room temperature and under adiabatic conditions, dinozebe starts to decompose after 15 days of contact with waste acids from the production of DNCTBB along with the formation of nitrous vapours. There was a slow decomposition reaction between the contents of the tank truck and the trace of dinozebe during the month of storage accompanied by an increase in pressure of the airtight and insulated tank truck. The accident resulted from inadequate cleaning between the two uses and the mixing of incompatible materials that triggered the sudden reaction. Measures were taken for other tank trucks containing the same acids: opening of manholes, cooling devices for tank trucks, etc. The use of temporary mobile storage containers without retention tanks was not allowed. Furthermore no risk assessment studies were carried out on the storage and treatment of waste acids. Material damage was evaluated at 0.36 MF.

ARIA 6004 - 03/11/1994 - 91 - LIMOURS

26.11 – Manufacture of electronic parts

In a company manufacturing printed circuits, a tank containing hydrochloric acid overflowed onto a retention tank. The acid was mixed with around 100 litres of sodium hypochlorite or sodium chlorite already present in the tank. A could of chlorine gas was formed and spread to the entire building. Five employees were intoxicated and hospitalised. One of them was under observation for over 48 hours. The fire-fighters neutralised the chemical and aerated the premises. The accident may have resulted from the failure of a solenoid valve. This accident would not have occurred if the tanks containing two incompatible chemicals did not have a common retention tank.

ARIA 10086 - 08/07/1997 - 81 - CASTRES

46.75 – Wholesale of chemicals

In a chemical depot, sodium hypochlorite and formic acid were accidentally mixed while transferring a product from a tanker truck to a fixed tank. Chlorine leaked from the vent of the tank until the valves were closed by the technicians. Ten people were poisoned (truck driver, depot staff and subcontractors) and hospitalised. A third party company analysed the conditions under which the truck was taken for delivery as well as the conditions for the treatment of the polluted tank.

ARIA 10851 - 26/02/1997 - 78 - LES MUREAUX

30.30 – Construction in aviation and space sectors

A driver connected one of the three transported containers to a tank containing 400 litres of 35% sodium bisulphite solution. A technician observed bubbling of the liquid in the tank and informed the driver who promptly stopped the transfer. A 98% sulphuric acid container that was properly labelled but covered by a plastic cover was accidentally connected instead of the bisulphite tank. The 5 to 10 litres of transferred acid reacted with the bisulphite. An SO_2/SO_3 cloud entered a neighbouring building effecting eight people located between 15 and 30 m from the unit. The eight people took ill and were hospitalised (3 for over 24 hours) and 150 employees were evacuated for 4 hours. The tank was inspected. The isolation and ventilation of the premises were improved and safety guidelines made more stringent.

ARIA 14377 - 05/06/1985 - 69 - CHASSIEU

20.1 – Manufacture of basic chemicals, nitrogenous chemicals and fertilizers, basic plastics and synthetic rubber

In a chemical wholesale unit, a cloud of chlorine was released into the atmosphere following the accidental transfer of hydrochloric acid into a tank containing sodium hypochlorite. Eight employees were poisoned. The facilities were moved and the storage tank organisation was consequently re-examined.

ARIA 15976 - 20/07/1999 - 45 - SAINT-CYR-EN-VAL

17.22 – Manufacture of paper items for toilet and domestic use

In a toilet paper production unit, a mixture of sulphuric acid and liquid bleach led to an exothermal reaction accompanied by the release of chlorine and hydrogen chloride. An absorbent product helped retain 150 litres of product that overflowed outside the retention area. Around twenty employees were evacuated. An outside company pumped the remaining product into two tanks. Failure of a valve at the foot of the sulphuric acid tank caused the acid to be spilled into the retention tank shared by the liquid bleach tank (inner separation wall not high enough). The acid damaged the transfer components of the tank causing the products to be mixed. No environmental impact was reported.

ARIA 21984 - 21/02/2002 - 59 - TOURCOING

13.10 – Preparation of textile fibres and spinning

While delivering 4 tonnes of sodium chlorite to a textile company (wool combing and lanoline production) at around 8.30 am, the driver read the loading plan upside down and emptied the wrong tank. About 50 litres of sulphuric acid was transferred to a tank still containing 700 litres of sodium chlorite. Chlorine dioxide vapours and a cloud of sulphuric acid were soon released. The area in the immediate vicinity was evacuated. The gas initially remained confined to a building housing the tanker truck as the mechanical extraction was insufficient. When the police and fire-fighters arrived, a safety perimeter extended to 200 m was set up around the site, all the staff evacuated and the residents informed (people were advised to stay indoors). The fire-fighters disconnected and emptied the transfer hose and broke a glass part of the roof to evacuate the gas. They subsequently sprayed 5 litres of caustic soda at intervals of 15 minutes to bring the pH to 12 – 13 which had dropped to 6.26. Around 3.30 pm, the pH was at 13.3 and the fire-fighters left the site. No casualties were reported and the weather conditions were conducive for atmospheric dispersion. Further to this accident, the operator was asked to prepare a report along with an impact study assessing the environmental consequences of the incident.

ARIA 27555 - 07/07/2004 - 59 - MARCQ-EN-BAROEUL

11.05 – Production of beer

In a brewery, the deliveryman transporting 2 tonnes of hydrochloric acid (HCl) connected the tank truck to the filling inlet of the sulphuric acid (H_2SO_4) tank, next to that of the HCl tank in the absence of a factory staff. Immediately after the pump was started, a cloud was formed and released via the blow off of the tank. The transfer was stopped after verification, but 500 litres of HCl has already been transferred to 1,500 litres of H_2SO_4. The staff from the buildings impacted by the cloud was evacuated. The zone was marked and entry prohibited. The tank was cooled with water until the arrival of a team from the transport company that transferred the contents into a tank pre-filled with 10 m^3 of water, slowing down and subsequently stopping the exothermic reaction. A CMIC chemical emergency squad measured chlorine concentrations to be 0.5 ppm. An initial analysis of the causes showed the absence of a formal transfer procedure that required a factory staff to be present for all transfer operations. Moreover, the deliveryman who normally delivered H_2SO_4 was filling in for the delivery of HCl on that particular day. The filling inlets of the two acids were close to each other and were protected by the same locked cabinet.

ARIA 29036 - 26/01/2005 - 74 - THYEZ

25.61 - Treatment and coating of metals

In an effluent detoxication station of a surface treatment plant, chlorine was released when 800 litres of sodium hypochlorite (NaClO) was accidentally transferred into a tank containing 600 litres of sodium bisulphite ($NaHSO_3$). These products were used to treat some of the effluents of the site. The accident occurred when 1,000 litres of soda lye, 1,000 litres of liquid bleach and a container transporting 24 carboys of hydrochloric acid were being delivered by a company trading in chemicals. The truck driver accidentally connected the NaClO tank of the vehicle to the filling inlet of $NaHSO_3$ despite the clear labelling. This occurred during the temporary absence of a factory employee who was away to get a power lift truck to unload the HCl. The chlorine spread to the effluent treatment workshop, outside the premises and also to the production building connected to the wastewater treatment plant by leaking pipe ducts. The rescue services set up a safety perimeter and the company staff was confined to the entry of the production workshop. A day-care centre and five local companies were evacuated and the 98 people were accommodated in the town gymnasium. The inhabitants of neighbouring buildings were confined indoors. Four employees of the surface treatment plant who took ill due to the chlorine emissions were hospitalised for further examinations. They resumed work later on in the day. The rescue services pumped out the product from the tank and lifted the safety perimeter. Further to the accident, the operator has planned to install double-locked filling inlets on the cases requiring the deliveryman and an accredited company employee to be present at the same time, make the shafts connecting the production workshop to the wastewater treatment plant watertight, organise first-aid training for company staff and regularly carry out evacuation drills. Upon the recommendation of the inspection authorities of classified facilities, the prefect has issued an order on 15 February requiring the implementation of procedures setting out the conditions for receipt and transfer of chemicals within one month and preparation of a safety report on the risks relating to the delivery, storage and distribution of chemicals in the factory.

ARIA 34431 - 07/04/2008 - 49 - LE MESNIL-EN-VALLEE

10.13 - Preparation of meat products

In a meat products factory, a deliveryman emptied sodium hydroxide into a tank normally meant for ferric chloride. Both these products were used for treating effluents. The deliveryman left the site without realising his mistake. A few days later, the operator found out this error due to the malfunctioning of the physico-chemical treatment plant.

A specialised company transferred the sodium hydroxide into a stainless steel tank brought onsite. During this operation, at around 11.30 am, an exothermic reaction took place in the tank and a light gaseous emission was released. The operator had not warned the specialised company that the sodium hydroxide had been polluted with ferric chloride, a product that strongly reacts with steel resulting in the production of hydrogen. The fire-fighters evacuated the 200 employees of the site and a set up a 100 m safety perimeter. The contents of the tank whose temperature had reached 55℃ were transferred into three 1m^3 plastic containers. The fire-fighters rinsed the steel tank and continued cooling and monitoring the containers where the reaction was in progress due to the presence of trace quantities of steel. Around 7.00 pm, when the temperature was back to normal, a specialised company took charge of the containers. The employees resumed work during the afternoon.

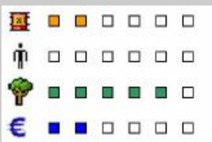
The inspection authorities of classified facilities were informed of this accident. The operator had planned to secure and improve identification of transfer fittings of tanks and the products would be delivered in the presence a factory employee qualified to supervise the operation.

Effects of water pollution by hydrocarbons

⑱ River pollution with transboundary effects

ARIA 35836 - 23/03/2007 – BELARUS - NC

49.50 – Pipeline transport



In Belarus, a leak was detected in a 377 mm diameter pipeline carrying gas oil causing 120 tonnes of hydrocarbons to be spilled in the DAUGAVA river for 5 hours. The emergency services contained the most of the gas oil at the source except 4 tonnes that managed to pollute the largest river of LATVIA, a tributary of DAUGAVA. The slick travelled at a speed of 2.5 km/h. The Latvian authorities were informed the following day and the pollution has already reached the country on 26/03.

The Latvian emergency services tried to install oil booms at the border but were unsuccessful due to the strong river current and the soil instability. The rescue work was further complicated by the need to seek special permission to carry out operations in the Belorussian soil. The rescue services installed oil booms over 1,800 m and absorbents over 3,000 m at 50 km from the border, as well as other lines of oil booms at 100 km from the border in a storage reservoir of a hydroelectric plant. These measures allowed the spilled gas oil to be recovered. The Latvian authorities alerted the masses on the pollution and the associated risks of using the river water. The Latvian environmental department regularly analysed the water to check pollution levels in the zone.

Environmental damage in the Latvian territory and the clean up operations were assessed at 170,000 euros.

⑲ Aquatic pollution of an oil terminal

ARIA 35835 - 12/09/2008 - ESTONIA - SILLAMAE

52.10 – Warehousing and storage

A hydrocarbon spill was detected on the coast near the port of Sillamäe. The inspection authorities responsible for environmental protection visited the site and discovered that the pollutant had escaped from a stormwater outfall of the neighbouring boiler room. The wind, which was blowing towards the ground, confined the pollution spill: 150 m of coastline were contaminated. A floating boom was set up to recover the hydrocarbons along the coast for storage in 200-litre barrels.

The plant designated to treat the 2,400 kg of fouled water and materials collected at the site estimated that 240 kg of hydrocarbons were contained in the spill, and these were produced from the bituminous schists found in the region, which also carried traces of phenol: the phenol concentration measured in discharged products varied from 0.04 mg/kg to 0.06 mg/kg.

The authorities concluded that at the adjacent oil terminal, the sump on the stormwater system oil separator in the rail tanker transfer station had not been drained for some time. Filling level monitoring and drainage operations had been scheduled in the emergency plan for this site but had yet to be formalised in a written procedure. Hydrocarbons mixed with rainwater reached the terminal's stormwater drains and then entered the boiler room pipe network, from where water is normally discharged into the sea via an outfall. A vacuum distillation effluent was recently discharged during rail tanker transfer operations, although hydrocarbon accumulation in the oil separator sump would have predated this incident.

Subsequent to this event, the stormwater system operator (not the same entity as the oil terminal) was levied a 100% tax increase on effluent discharge (from €13,360 to €26,720) and required to pay another €4,000 in fines as the party liable for environmental discharges. The oil depot installed alarms on its drainage network.

Effects of water pollution by hydrocarbons

The December 2000 Water Framework Directive that brings together the EU states around the common objective of improving the quality of water and aquatic environments by 2015 implies an enhanced protection of the aquatic environment against pollution.

In the event of failure of preventive devices, the accidental release of liquid hydrocarbons can pollute the water bodies, contaminate groundwater tables, streams and coastal regions, and permanently modify aquatic flora and fauna or prevent drawing drinking water from the natural environment.

Several accidents registered in the ARIA database recall that detection and response times of rescue workers must be as short as possible to reduce the amount of material spilt and prevent spreading of pollution and its effects (ARIA no. 27412, 32890, 34351).

When confronted with surface water pollution, rapid action of rescue workers is essential to keep the consequences of the accident on the natural environment, population, local economic and industrial activities to a strict minimum. Generally speaking, the efficiency of the operations depends on the information on the released pollutant, environment and the potential targets. This calls for alerts from competent departments, local authorities, and the population if required (ARIA no. 30486) and the implementation of adequate mitigation devices: oil booms (ARIA no. 32322, 32890, 35402), use of absorbents or dispersants (ARIA no. 2902, 11197, 31517), skimming of the water surface using any appropriate device adapted to the situation (ARIA no. 8387, 15836, 32890, 34351, 35402, 35825) depending on the properties of the spill (density, etc.).

The rescue operations have ensured that recorded cases of accidental pollution have a limited environmental impact and their spread is curtailed. However in some cases, the pollution travels great distances contaminating rivers and the sea (ARIA no. 14142, 28792, 30698) and more or less severely impacting the coast (ARIA no. 30486, 34351).

Cases of impact on the fish fauna are often observed at varied degrees: mortality, damage to habitat and especially to spawning or breeding grounds (ARIA no. 729, 7968, 8872, 9990, 15986, 32030) or modification of the nutritive value of fishes (ARIA no. 8677,13841,13961) and even a total ban on consumption (ARIA no. 8711,8735). The impact can also be indirect though an imbalance effecting the different linking components of the food chain: flora (ARIA no. 15328, 14545), substrates (ARIA no. 14792, 15038) or even macro or micro-invertebrates (ARIA no. 11896, 13599, 13961). Aquatic birds may also be victims of such pollution (ARIA no. 7883, 21317, 30936, 32890).

Moreover, the consequences of an accidental spill in a water body may be worsened by the weakening of the flora or fauna on account of a previous accident, chronic pollution or during periods of low-water levels (ARIA no. 3824, 9410).

The surface water contaminated or covered with hydrocarbons poses a potential health hazard to man. Apart from disturbances on account of odour nuisance (ARIA no. 15038) and impacts of fires and explosions (ARIA no. 12507, 23637, 32592), preventive or protective measures are generally taken to protect water catchments intended for human consumption (ARIA no. 24512, 27638, 32038, 33722, 34262), irrigation (ARIA no. 8462, 18407), and water-related activities (ARIA no. 9825) such as fishing or gathering of shellfish (ARIA no. 31023, 31347, 34351). Surface water pollution is sometimes accompanied by soil pollution that risks contaminating groundwater tables that often form the only natural source of drinking water (ARIA no. 762, 9031,12896).

Such incidents of pollution can also have an economic impact further to stoppage of water supply (ARIA no. 12468), clean up operations (ARIA no. 9990, 32890, 34351), production downtime or interruption of commercial and economic activity (ARIA no., 32652, 34351) or loss of commercial value of fishes (ARIA no. 7968, 8711). The polluting facilities often reach an out of court settlement to compensate the aggrieved third parties in less serious cases of poll--ution (ARIA no. 8711, 8734, 10704) but may be condemned to pay fines or serve a suspended sentence (ARIA no. 12426, 26856).

Lastly, diagnosing the impact and extent of pollution on the environment (ARIA no. 24512, 26832, 27412) or food chain, possible clean up operations (ARIA no. 19941, 23862, 27581, 34761, 34951) and inspection and monitoring of the impacted or threatened environment (ARIA no. 14846, 21385, 24358, 24512, 29760, 33342, 35760) are the various stages involved in the restoration of the effected environments.

With a view to avoid compromising the progress made in reducing the release of chronic waste in respect of the objectives laid down by the European directive, the efforts must continue and be furthered to prevent accidental spills: implementation of appropriately sized and regularly maintained retention tanks, containment ponds designed to recover accidental spills, carefully placed detection devices, monitoring of hydrocarbon pipelines (corrosion, ageing, external stress), etc.

In the event of a possible failure of preventive measures, it is advisable to have a genuine pre-implemented organisational set up to detect and assess the impact on biotopes and biotic community, property and activities to take action under the best possible conditions.

The accidents whose references are not underlined may be consulted at:

www.aria.developpement-durable.gouv.fr

ARIA 7968 - 08/01/1996 - 80 - AIRAINES

10.51 – Dairy operation and cheese manufacturing

In a diary, a joint ruptured on the valve of a tank containing heavy fuel oil. The hydrocarbons spilled into a completely permeable retention tank. The spill reached the rain water network to finally contaminate the AIRAINES river. A fish farm located downstream was seriously effected: 55 tonnes of trout were deemed unfit for consumption. The opportunity cost was assessed at 1 MF. The rescue services installed oil booms. The tank was subsequently repaired.

ARIA 8711 - 22/03/1996 - 71 - BRANGES

49.41 – Road freight transport

A faulty operation caused fuel to spill from a jerrican leading to the pollution of a reach (affluent of the SEILLE river). The fire-fighters installed oil booms and used absorbent products. The fish were deemed unfit for consumption. An out-of-court settlement was reached on compensating victims and ensuing compliance of operations.

A0IA 9825 - 20/08/1996 - 59 - VIEUX-CONDE

25.50 - Forge, drawing, stamping; metallurgy of powders

Hydrocarbons from a collector of rain water polluted the JARD river and the pond of AMAURY (aquatic base).Oil booms prevented the pollution from spreading and facilitated pumping operations and the use of absorbent. All aquatic activities were suspended for a few days. The pollution occurred due to the malfunctioning of an oil trap in an automobile equipment manufacturing plant during a storm, as well as due to the inappropriate configuration of the sewage network supplying the urban wastewater treatment plant whose storm overflow is connected to the JARD river. The waste outlet of the plant was connected to the rain water network. A new decanting device/oil separator was installed and 15 tonnes of sludge/hydrocarbons were removed from the rain water collector.

ARIA 9990 - 26/06/1996 – UNITED STATES - SIMPSONVILLE

49.50 – Pipeline transport

Hydrocarbons leaked from a 36'' diameter and 2,500 km long pipeline. Nearly 3,800 m³ of diesel fuel spilt into a river that over 35 km suffocating over 34,000 fishes. 300 people were required for the clean-up operations, 7 oil booms were installed, 15 skimmers and 20 pumping trucks were used. The company owning the pipeline had to spend 6 M$ towards the river cleaning operations.

ARIA 12507 - 27/02/1998 - ECUADOR - ESMERALDAS

49.50 - Pipeline transport

Subsequent to the torrential rains due to the El Niño-Southern Oscillation climatic phenomenon, a landslide caused the rupture of a pipeline located at 12 km from a 500 km oil terminal transporting oil from Amazonia to the pacific coast. Around 2,500 m³ of oil spilt into the rivers and the ocean. The explosion and the fire that followed destroyed 160 homes. The fire spread to the wharfs of the port but spared the refinery and the gas pipeline. Fire waves as high as 10 m were observed. Seven persons were killed, 110 sustained injuries including 40 people who suffered 50% burns. 40 people were reported missing and 600 people evacuated. The rescue operations lasted 6 hours and were complicated due to water shortage following the rupture of pipelines.

ARIA 13841 - 07/07/1998 - 60 - THOUROTTE

20.30 – Manufacture of paints, varnishes, inks and putty

Hydrocarbons from an ink manufacturing plant polluted the MATZ river over 9.5 km. The waters, extremely destructive to the fish fauna, altered the taste of the fish and polluted the sediments.

ARIA 13961 - 06/01/1997 - 60 - ERAGNY-SUR-EPTE

21.20 – Manufacture of pharmaceutical preparations

In a pharmaceutical company, hydrocarbons leaked from a pipeline into the EPTE canal over a distance of 10 km. The subsidence of the canal due to draught triggered the pollution. The benthic fauna was disturbed and the taste of fish strongly modified.

ARIA 15038 - 06/03/1999 - 67 - SAINT-NABOR

08.12 – Mining of burrow and sand pits, extraction of clay and kaolin

In a quarry, significant quantities of hydrocarbons leaked from an underground tank (7,500 litres) polluting the WESSERGRABEN and EHN rivers. The residents, on detecting the smell, informed the fire-fighters who installed dams to contain the fuel spill. The operator sent earthmoving machines to create a small retention tank to pump out the fuel. The tank was emptied and 1,000 litres of fuel was recovered in 4 hours. Legal proceedings were instituted on account of the damage caused to benthic fauna, hydrocarbon deposits on aquatic flora, degradation of river banks and iridescence of the waters. The pollution may have resulted due to the corrosion of the tank.

ARIA 18407 - 01/08/2000 - SPAIN - MADRID

35.13 – Electricity supply

In a nuclear power plant, 25,000 litres of fuel leaked from a tank (containing 100,000 litres in total) following the malfunctioning of a gauge and other checking devices. The spill polluted 8 km of the river TAGE and was retained by a small oil boom. About hundred members of the Spanish civil protection department participated in the clean up operations using pumps, oil booms and chemicals solidifying fuel. These operations were scheduled for two days. The local authorities prohibited the consumption of water from the river and its use for farming. The Spanish environmental authorities carried out tests to measure the extent and gravity of pollution.

ARIA 24512 - 05/03/2003 - 78 - LE VESINET

72.19 – Research-development in other branches of physical and natural sciences

Seven m³ of domestic fuel overflowed and spilled into a drain before spreading onto the ground of the boiler room when a tank outside a radioprotection institute was being filled by a supplier in the morning. After having passed trough the site's rainwater collector, the spill polluted the SEINE river and the soil around the underground tanks. The drawing of water from the SEINE river and the adjoining water catchments to produce drinking water was stopped for 2 days. An internal investigation was carried out in the institute. The tanks were old and not fitted with stop valves. A prefectural order required cleaning of the internal rainwater network, disposal of polluted soil, soil tests and clearing of the facility's administrative situation. The conducted studies revealed a soil polluted by hydrocarbons to a depth of 10 m. However the ground water for drinking water supply was not effected. A prefectural order required several measures to be taken: partial removal of polluted land, implementation of a water tight cover over the polluted area and monitoring the quality of ground water.

ARIA 27412 - 23/06/2004 - 69 - COLLONGES-AU-MONT-D'OR

20.13 – Manufacture of other basic inorganic chemicals

Heating fuel oil from a chemical plant used by a glass furnace as fuel polluted the SAONE river. The alert was sounded at 6.00 am by a patrolling team. The operator promptly took measures to prevent the pollution from spreading by installing fenders at the outlet of the plant's aqueous effluent pipe. After 1 hour and 30 minutes, this device was replaced with a 45m oil boom upon the arrival of fire-fighters. The major portion of the pollution was contained in a plant's sewage station that was cleaned by a specialised company though pumping. The hydrocarbons captured by the oil boom were also pumped out. A few 1 to 2 m² patches of pollution drifted away and except for the iridescence and oils on the surface of the river only oily stains on the rocks and plants remained near the site of emission. The zone was cleaned up on the day itself. The hydrocarbon leak came from facilities transporting heating fuel oil to the melting furnace but its origin was not clearly established. The 2 to 3 m³ retention around the pumping equipment had overflowed in all likelihood since a 4 m² oil spill was seen below. Given the viscosity of the product, the pollution had slowly contaminated the industrial water network; the operator was required to carry out a study to study to determine the causes of the accident and take the necessary measures to prevent any reoccurrence. The extent of the pollution had to be marked out and the polluted zone cleaned up. Investigations aimed at identifying the possible consequences of the fuel spill on the soil had to be carried out as well.

ARIA 28792 - 23/12/2004 - MEXICO - VERACRUZ

19.20 – Crude oil refining

In a refinery, an explosion (in a pumping station, site's fire hall?) caused a pipeline to rupture resulting in four people sustaining injuries including one case of serious injury. An 800 m³ oil slick was formed on the COATZACOALCOS over 1.3 km. The black slick, directed to the Gulf of Mexico at 50 km from the accident site by the strong winds and river currents, polluted the beaches: swimming was prohibited in two of the beaches. Oil booms were installed to prevent the slick from spreading. The navy was busy in site clean up operations estimated to last 3 months. Ducks, several fishes and aquatic flora were effected. The fishermen of the region filed a complaint. The pipeline was re-commissioned two days after the accident.

ARIA 32675 - 12/01/2007 - 33 - AMBES

46.71 – Wholesale of fuel and related products

The bottom of a 13,500 m³ crude oil tank ruptured at 8.15 am in an oil depot. Even though the barricades around the retention tank resisted this surge effect, 2,000 m³ of crude oil overflowed and spilled onto the ground and roads, severely contaminating them before seeping down to the water table and the ditch network. The spill essentially remained confined to the site and the sewage system but 50 m³ of crude oil flowed into the river via a storm drain and pipeline casing. The successive tides polluted up to 40 km of the banks of the GIRONDE, DORDOGNE and GARONNE rivers and 2 km of the ditch network.

The operator triggered the internal contingency plan and covered the retention tank with foam to prevent risk of ignition and curtail the dispersion of hydrocarbon and hydrogen sulphide vapours. The authorities evacuated 12 employees of neighbouring companies, established a safety perimeter, stopped movement and traffic in the secondary highway adjacent to the site, informed the masses and neighbouring power house and measured the H_2S concentration. The product spilled onto the drains and the retention tanks were channelled to the site's settling tank and subsequently transferred to empty tanks: 6,000 m³ of crude oil was pumped.

The operator proceeded to site clean-up (manual recovery, barriers, pumping, absorbents, dispersant additives, etc.) under the supervision of three experts in surface water, soil and air. The products and other waste material were disposed off in specific sites. The underground water was tested. 13,000 m³ of clean-up water containing foam compound (COD: 2.7 g/l) was stored and treated onsite using the activated sludge process.

A small leak in the tank was detected the previous day. According to the operator, the draining operation was postponed due to the potential risks faced by the technicians and the subcontractors if the floating roof of the tank had been blocked at night. According to the operator and the inspection authorities, a site visit report dating back to 2006 indicated corrosion at the bottom of the tank and an 80% loss of thickness. This consequently resulted in repair operations. Furthermore, the inspection authorities specified that no procedure was planned in the site's safety management system to manage the emergency situation arising on the day before the rupture.

To have an idea on the possible causes of the accident, a prefectural order issued to the operator demanded the submission of a summary report on the conclusions and recommendations drawn from the ten-year leak tightness and integrity inspection reports on operational tanks. The operator was also required to justify all corrective measures that were implemented or would be put in place if required. A third-party expertise was carried out.

Operations will resume only after the site has been fully drained and the other tanks inspected. A legal investigation was carried out.

ARIA 32890 - 21/06/2003 - SWEDEN - GOTEBORG

46.71 - Wholesale of fuel and related products

There was a spill of 328 tonnes of heavy fuel oil in the oil terminal during discharge of the product from a ship vessel to a storage tank.

At 22.30 p.m., the discharge of heavy fuel oil from a ship vessel to storage tank No 375 was started by two operators. At the same time discharging to tank No 304 was ongoing. when reading the level indicator the operators noticed that the level in tank No 375 was stable. The operators tried to increase the flow to tank No 375 by reducing that of the tank No 304. At 01.52 a.m. the operators discovered that the manhole of tank No 375 was open and oil was flowing out to the ground outside the tank and to a neighbour company in the harbour. The operators closed the valve to tank No 375 and also the manhole and informed the terminal manager and a local cleaning company. At 03.00 a.m. the cleaning operation started. The harbour service staff inspected the harbour rain water drainage system and observed that it was full of oil. oil booms were placed in the port harbour. Cleaning procedures continued till the following day and the authorities were informed about the accident.

The first indications of pollution were noticed by the Swedish Coast Guard. Approximately 50 metric tons of heavy fuel oil contaminated the harbour open rain water drainage system and then the sea, polluting 20 km of coastal area The spill resulted in a contaminated area in the harbour of approximately 2000 – 2500 sq metres. Fishermen tools, hundreds of yachts and several birds were contaminated too. The total economic loss resulting from the accident was approximately 2.7 million EUR.

The major latent factors which contributed to the accident included lack of communication between the 2 shifts during the changeover, absence of a check list for tank preparation following maintenance and no double checks of equipment before start-up, as well as non-compliance with operating procedures. Due to the Midsummer Eve holiday there were fewer personnel in the oil terminal than usual. The shift foreman was on vacation and the terminal manager had taken over the foreman's work. The wide consequences of the accident are due to the wrong reaction of the employees who failed to inspect the tank even though they spotted a problem, non-compliance with the emergency plan that stipulates that the port authorities must be promptly informed, absence of retention and valves on the rain water drainage network. Moreover, the rain water drainage system equipment and the booms placed in the open port harbour were less efficient given the density of the product (greater than 1). Density is an important factor in detecting pollution: the hydrocarbon clusters did not float on the soft waters of the harbour but floated only on sea water.

After the accident, operational measures, emergency procedures, organisation, communication and the terminal design were improved.

ARIA 34351 - 16/03/2008 - 44 - DONGES

19.20 – Oil refining

While loading 31,000 m^3 of bunker fuel in a ship, a leak in a refinery transfer hose resulted in a major oil spill in the Loire estuary.

At 4.10 pm, a person on a barge observed the presence of hydrocarbons on the water surface and sounded the alert. At around 4.45 pm, a roundsman identified and isolated the leak at 500 m upstream to where the hydrocarbons were detected.

The internal contingency plan was triggered at 5.00 pm and the inspection authorities of classified facilities were informed. A recovery ship was stationed at the mouth of the river while two trawlers recovered hydrocarbon pellets from the river.

The public ban on access to several beaches and fishing in the river that was in place subsequent to the spill was gradually lifted between the 4 and 18 of April. Over 750 people were involved for three and a half months in cleaning up the 90 km of polluted banks (6,170 tonnes of waste recovered and stored onsite before disposal). The operator bore the cost of 50 M euros to cover for the damage incurred, clean up and compensate effected businesses.

Investigations revealed that the leak was detected only after 5 hours leading to 478 tonnes of fuel being spilled of which 180 tonnes flowed into the Loire estuary.

A 16 cm² longitudinal breach caused by corrosion localised under the insulator was observed upon examination of the hose. The corrosion resulted from a water leak in the vertical pipe. Water seeped beneath the insulator, caused corrosion and subsequently caused the fuel pipe to rupture. Despite several defects detected the previous month on the same rack, the operator failed to revise this inspection programme to take into account the specific risks presented by this line given its proximity with the river banks. The effected fuel line was completely stopped and the inspections on the entire rack revealed several corrosion points on other lines that required repair.

The operator was required to implement several additional initiatives and measures:

- Extending inspection operations to other pipes in the site along with measurement of thickness at sensitive points (supports, spurs, etc.)
- Moving the layout of the service water mark so that it is not in a vertical position with respect to the insulated pipe
- Using a leak detection system along with a remote alarm in the control room to constantly monitor pipes located near the river
- Modifying the ground below the rack to channel any accidental spill to an adapted recovery network
- Installing a device to monitor the quantity of products leaving the tank and entering the corresponding transfer hose

It was also planned to consolidate the available emergency measures in the event of accidental pollution of the Loire river.

ARIA 34951 - 05/01/2006 - CROATIA - LEPOGLAVA

31.09 – Manufacture of other furniture

Heavy fuel oil leaked from a pipeline connecting a storage capacity to a boiler in a furniture plant. The residents noticed the hydrocarbon pollution in an adjacent stream. The environmental inspection authorities were alerted by the emergency services. The internal and external emergency plans were triggered.

Voluntary first-aid workers installed an oil boom on the water body to contain the la pollution. The site manager and the mayor were onsite the following day. A 3 mm wide hole was observed on the pipeline.

A specialised firm carried out site clean up operations for 14 days. Low winter temperatures made the operations easy. The site clean up and repair operations were estimated at 100,000 euros. The accident underlined the importance of a good coordination among the various authorities (environmental protection, water table protection, fire protection and occupational safety) to avoid such incidents from reoccurring.

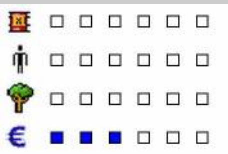
Floods

Source: operator

⑳ *Flooding of an industrial site*

ARIA 35426 - 01/11/2008 - 43 - SAINT-GERMAIN-LAPRADE

21.20 – Manufacture of pharmaceutical preparations



A pharmaceutical plant on a 55 hectare platform out of which 15 hectares were used was flooded (ARIA 35427) with 20 cm to 1 m of water due to torrential rains (300 mm in a few days including over 100 mm in less than 24 hours – The French metrological department put the region on “red alert” (highest level of alert) due to the rains.)

The site was on internal alert before the rise in the water level. The internal emergency plan was triggered. Thirty employees of the company evacuated or place the equipment and products at heights at around 4.00 pm. Safety alert was sounded in the company (safety fold back phase: production stopped, planning of power cut sequence).

Leak detectors, especially gas indicators were not functional after the power supply was stopped. The company staff and voluntary fire-fighters patrolled the site. No pollution was observed except for 2 to 5 litres of hydrocarbon (Isopar G) and 200 g of powder in the laboratory that had spilled. On the other hand, significant damage on account of water was reported (building partitions, documentation, electronic equipment that was not placed at heights)

Additional resources were called in: trucks and power lift truck operating at great heights were used to move the products. Two high-speed pumps (850 m³/h) provided national civil safety department of the French Home ministry were used to rapidly evacuate the residual water.

The production facilities, cooling towers as well as electric equipment and rotating machines were re-commissioned with care and monitored.

A hydraulic study was commissioned by the metropolitan authorities of the industrial zone. The operator updated the internal emergency plan by including the flood situation and fine tuned his crisis management action plan (human and material resources).

The torrential downpour on the industrial area spread out over two towns was recognised as an act of God on 29 December 2008 (Official Gazette dated 31/12/2008).

Floods

The flooding of a facility resulting in its total or partial submersion in variable lengths of time is due to various reasons: torrential rains for extended periods of time (ARIA 35426), flooding of a water body (ARIA 26459), obstruction of the sewage network (ARIA 29645), rupture of a dam (ARIA 15513, 26457), rising of the water table, etc.

The two main accident typologies observed include release of dangerous materials or pollutants (ARIA 160, 1699, 4570, 4909, 4910, 6413, 9260, 21611, 21631, 23053, 25231, 27920, etc.), as well as fires (ARIA 4743, 5677, 17023, etc.). The most famous fire accident is undoubtedly that of the Mohammedia refinery in Morocco in 2002 (ARIA 23637) where the floating hydrocarbons ignited upon contact with the walls of high-temperature installations.

Are these accidents just destined to happen? Not always. The analysis of accidents recorded in the ARIA database regularly highlights implantation errors, flaws in design or operation of sites that contributed to the rise in water levels or worsened their consequences: storm drain networks of inappropriate size or that are poorly maintained (ARIA 29645), unsafe storage (ARIA 27920).

Rise in water levels, “waves” or mudflows either result in equipment damage, rendering motors, pumps, compressor, electric and IT equipment required for the site’s safety (ARIA 26459, 26460, 29645, 29646, etc.) non-functional or destroy labelling of dangerous substances (ARIA 21600).

In addition to equipment damage, the problem is further compounded by production losses arising from stoppage of work along with technical unemployment that may last several weeks or even months (ARIA 16975, 16976, 32258, etc.). It is sometimes hard to express damage as a figure such as financial assessment of losses pertaining to IT information, prototypes or intervention plans.

After periods of floods, there is a risk of collateral accidents that needs to be closely studied. Checks must be carried out primarily focusing electrical components (mechanical relays, sensors, earthing, etc.) crucial to the safety of the site (ARIA 4743) while separating intense and weak current circuits.

The 2001 report of the Intergovernmental Panel on Climate Change (IPCC) has forecast an increase in torrential rains in middle and high latitudes of the northern hemisphere. It would be advisable to anticipate even more serious events than ones already observed and implement appropriate preventive measures: upgrading equipment vital to the safety or smooth functioning of the site (ARIA 15513), securing and positioning of water-sensitive material at heights and material likely to be swept away by floods (ARIA 26004), device to measure the rise in water level with stoppage of operations and folding back of facilities when the level crosses a predefined water mark (ARIA 26459), flood storage area (ARIA 26460) or flood risk-free zones facilitate rescue operations.

Generally speaking, the danger studies must highlight actions that can be carried out in the time between the sounding of the alarm and the predictable occurrence of the flood. These actions must be implemented on a permanent basis. The aim is to keep the list of actions to a strict minimum in the time period following the alert and have simple measures that can be rapidly implemented.

Pre-defined mitigations measures adapted to the risks help complement the risk prevention plan and limit the consequences of an accidental increase in the water level: drain or pumping systems to reduce submersion times, rescue devices in the event of increase in water levels (rescue boats, power lift trucks operating at increased heights, etc.), rescue services deployed on a priority basis to help the distressed population. Compiling a file of sub-contracting companies along with the training of all involved players ensures smooth rescue operations that are often needed after floods.

Nevertheless, these measures must be proportionate to the risks and vulnerability of the stakes involved. In flood-risk zones, reference floods and the predictable kinetics of the rise in water level must constitute the basis of such measures. A detailed risk analysis must be carried out that must examine scenarios involving dangerous reactions likely to be triggered, loss of utilities and fall of equipment. Buoyancy studies can prove useful.

Technical measures must be backed by organisational ones such as forecast of heavy rains or floods.

The frequency and gravity of floods in the recent past confirm the need to take site submersion scenarios into account for danger studies involving classified facilities.

Moreover, it must be noted that building private or public facilities (roads, fills, traffic lanes, sewage networks) and more broadly any structure modifying water flows (ARIA 29646) near classified facilities may increase the risk of flooding: inaccurate proportioning of drain pipes, various players involved in the maintenance of storm drains, etc.

For further information, a study on atmospheric precipitation and floods can be downloaded from the website: www.aria.developpement-durable.gouv.fr .

The accidents whose references are not underlined may be consulted at:

www.aria.developpement-durable.gouv.fr

ARIA 4743 - 13/10/1993 - 57 - SAINT-AVOLD

22.29 – Manufacture of other plastic items

A fire broke out in a building adjoining a company specialised in manufacturing plastic containers and dust bins. Significant resources were deployed to quickly bring the blaze under control. Part of the stock along with the roof of the building was destroyed. The accident resulted from the malfunctioning of electric circuits subsequent to floods. Material damage was estimated at 1.4 MF.

ARIA 17318 - 27/12/1999 - 33 - BLAYE

35.13 – Electricity supply

During a violent wind storm accompanied by heavy rains, the production site of a power plant was hit by an 80 cm water wave. Administrative buildings, workshops, company canteens and the cooling water pumping system were all flooded. A part of the pit housing the pipes was submerged and the drip collection tank overflowed due to excess water. According to the operator, 90,000 m³ of water was pumped out and emptied into the Gironde river. The water that seeped into the underground tunnels led to the failure of equipment and circuits vital for safety (total failure of the emergency injection pump and enclosure sprinkler pump and partial failure of the emergency raw water pump).

ARIA 21600 - 25/10/2001 - 26 - LIVRON-SUR-DROME

46.75 – Wholesale of chemicals

In a warehouse of a company specialised in agricultural treatment products, an operational error lead to a violent reaction resulting from the mixing of potassium permanganate with sulphur. Two 1 tonne containers caught fire and emitted toxic fumes. Some containers had lost their identification labels following incidents of flooding with 50 cm of water in and around the site a few days before the accident.

ARIA 23637 - 25/11/2002 - MOROCCO - MOHAMMEDIA

19.20 – Crude oil refining

The OUED MALEH dam overflowed following continuous torrential showers that lasted several days and flooded the facilities of a refinery located in the heart of the port of Mohammedia. The site's production was stopped around 4.00 pm due to the water level that rose to as high as 1m at a site in the facility. A violent fire ensued, as well as several explosions of tanks, electrical equipment (transformers) and pipes. At around 8.00 pm, two fire areas still persisted in the gas and crude oil sectors of the refinery. The fire was extinguished after 20 hours of struggle under difficult conditions and required considerable human and material resources: 3.5 million m³ of water, 30 tonnes of chemicals (foam compounds, etc.). Two persons died and four were injured despite the contradictory information published on human causalities. Significant material damage resulting from the accident led to the closing of the refinery and suspension of all activities. A crisis unit chaired by the Moroccan Home Secretary was set up. France dispatched a technical operations team in the days following the accident. 17 other industrial units were damaged by the floods. Based on the initial findings of the conducted surveys, the roof of one of the storage tanks had given in and another had cracked during the rainstorms. Petroleum products possibly flowed into the tanks and were mixed with the flood water. The hydrocarbons floating on the water surface caught fire upon contact with the high-temperature installations. This explains how fires were triggered in the various fire areas and that were fuelled by short circuits due to flooding of the facilities.

ARIA 26004 - 01/12/2003 - 69 - CHATILLON

23.51 – Cement production

A cement production plant was flooded following torrential rains that poured down the region. The 35 employees of the plant were on technical unemployment for an undetermined period of time. None of the storage tanks (liquid waste tank, fuel tank) were submerged by the flooding river. All retention proved to be waterproof and the water level did not cross their upper mark. The transfer area and its recovery pit were protected at the start of the flood by a circle of cement bags stacked to four levels that proved to be efficient. The rest of the facility especially the electrical equipment suffered considerable damage.

ARIA 26459 - 02/12/2003 - 13 - TARASCON

17.11 – Production of paper pulp

The RHONE river overflowed due to heavy rains and flooded a paper mill located in an industrial area. This upper tier seveso site produced kraft paper pulp from softwood bleached with oxygen, hydrogen peroxide and chlorine dioxide also stores black liquor, fuel oil, methanol, chlorate and several tonnes of wood. Further to three flooding incidents that occurred in 2002 and 2003, when the RHONE river rose to 10.27 m (French surveying and levelling), various measures were taken in the site: risk of flooding included in the danger studies, drafting of guidelines to secure the site, production workshops, black liquor boilers and turbines recorded at 10.56 m, 15 m and 21 m (French surveying and levelling), storage with 0.7 m retention tanks, anchored tanks, boxing up electrical equipment, piping mounted on racks (only water pipes were underground). On 1 December, the site was alerted to floods by fire department and consequently operated with reduced staff right from the next day. Given the unrelenting rise in the water level, an emergency procedure was implemented according to the water level: at 6.4 m NGF, implementation of a 600 mm diameter bladder on the pipes to prevent rain water from spilling on to the acidic effluents; at 9 m NGF, evacuation of staff and securing of the site by 25 employees (total stoppage of facilities, boxing up exposed equipment).The RHONE reached 10.50 m NGF on 2 December at 3.00 pm and 11.3 m NGF on 3 December at 3.30 pm. Since the site was completely flooded, the inspection of safety devices on facilities was carried out on boats. Despite IT, electricity and telephone communication failure, the operator could be reached on his mobile throughout the course of events. The water currents swept away 4,500 tonnes of wood ((ripping off the enclosure) and empty or sparsely filled containers (less than 3 m³ of products); on the other hand the anchoring of storage tanks proved to be efficient. Environmental impact was limited as there was no leakage of chemicals. Material damage, production losses and cost of site refurbishment were estimated at 11 M euros: 6 000 tonnes of wood and 2,000 tonnes of paper pulp were soiled or carried away by the current, 400 submerged motor units were taken down and cleaned, electric devices were damaged and the archives were dried using cryogenic processes.

ARIA 26460 - 04/12/2003 - 13 - SAINT-MARTIN-DE-CRAU

20.51 – Production of explosives

An upper tier SEVESO site manufacturing explosives was flooded following heavy rains. The products involved are not sensitive to water. A 15 hectare marshland located upstream to the site serves as an outfall for water overflowing from neighbouring lands. A 150 m^3/h lift pump pumped out the excess water from the marshland via a pipeline to the CHAPELETTE marshland situated northeast. A non-stop and heavy downpour caused the water level to rise in the LANGLADE canal running southwards and adjacent to the plant. The gate valves that were shut for unknown reasons were unable to evacuate the excess water from the overflowing canal. Water swept into the site from the south west direction in form of a wave and drained into the 15 hectare marshland. The lift pump, completely submerged due to the rapidly rising water level could not prevent the flooding of the site where the water level reached 1.2 m. The operator installed four mobile pumps available on the site and requisitioned emergency pumps from neighbouring industries. A 2,000 m^3/h capacity helped curb the rise in water level. After a week of pumping, the water level in the CHAPELETTE canal returned to normal. Despite the risk of exposure to water, a transformer suffered no damage. Even though the storage and production sites were not impacted, the two-week long production stoppage resulted in losses estimated at 105 K euros. The operator updated the internal contingency plan by adding the particulars of the companies capable of providing emergency pumps.

ARIA 27920 - 13/01/2004 - 37 - AUZOUER-EN-TOURAINE

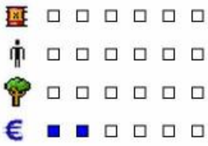
20.14 – Manufacture of basic organic chemicals

A chemical plant manufacturing basic organic chemicals was partly flooded when the reactors were being washed. The washing water (acrylic emulsions) got mixed with the flood water due to the backflow of the water in the pipeline and in the mouth of the drain located in the traffic lane. The abrupt rise in the level of the La BRENNE river submerged the efflumeter containing effluents from the sewage treatment plant. Red coloured water flowed out of this efflumeter and spread onto the ground near the plant. Each time the La BRENNE river flooded, a “low” point at the main fire door caused the site to regularly flood. The inspection authorities for classified facilities observed the facts and ordered a hydraulic study taking into account data on the river and a study on the measures to be implemented to prevent the flooding of the site (removal of the “low” point, protective dam, transfer of sensitive stock to flood risk-free zones, etc.) and carry out identified operations. The prefectoral decree dated 16/02/04 has ordered the protection of the site against floods.

ARIA 29645 - 04/09/2002 - 13 - PEYPIN

20.14 - Manufacture of basic organic chemicals

Following violent rainstorms, the runoff water in an industrial zone could no longer flow into a mud-clogged pipeline serving a pharmaceutical plant. The arrival of water caused the retention tank of the site to overflow, thereby flooding the fire premises located in an underground pit. As a safety precaution, the water triggered the start of the motor pump (whose motor was damaged by the entry of air), that activated the water and foam networks of the storage buildings. To reduce the chances of recurrence of such an accident the operator has elevated the entry point of the fire premises, ensured surveillance of the storm drains and carried out maintenance of existing structures.

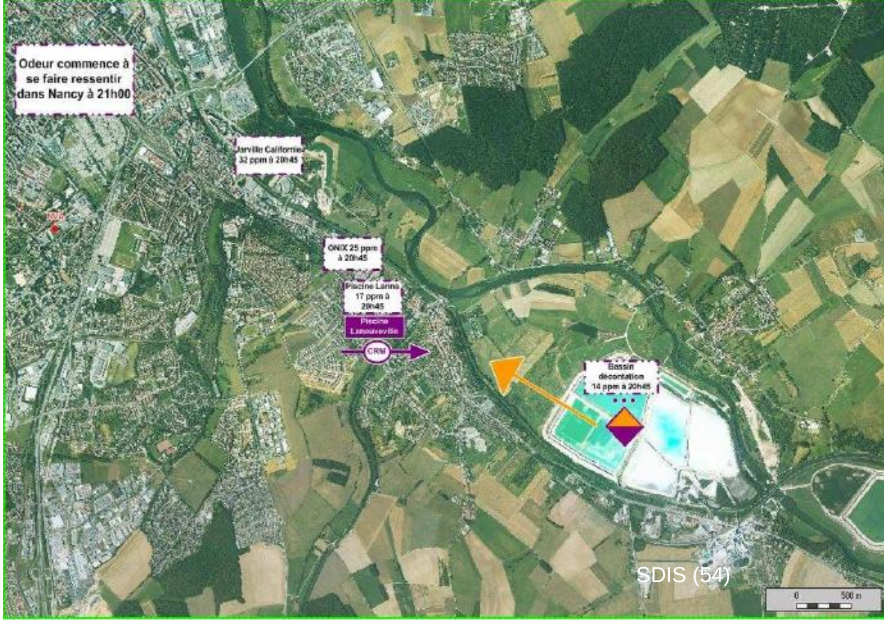


ARIA 29646 - 01/09/1993 - 13 - ROGNAC

52.10 – Warehousing and storage

An 11,000 m^2 warehouse storing crop protection products, stuffed toys and life jackets was flooded following a heavy downpour. The operator prepared, repackaged and palletised the stored products. The site is located on the foot of a hill and is encircled by a railway track whose raised portion upstream to the site forms a dam. After three days of intense downpour, the rain water from the hill that involuntarily flowed into the dam could not be contained. The overflowing of the dam led to the offices, storage cells and the packaging workshops being flooded by 50 cm of water for four hours. The IT network was down. Material damaged was assessed at 7 MF (the precise day of the accident was not known). After a year (October-November 1994) and under similar conditions, a second wave flooded a warehouse with 80 cm of water for ten hours. Further to these new flooding incidents, the town built an underground pipeline connecting the BERRE canal as well as a retention basin upstream to the industrial site whose excess water flowed into the canal. The operator, on his side, built 20 cm high sleeper walls between the entry points of the storage cells and ensured constant monitoring of the site.

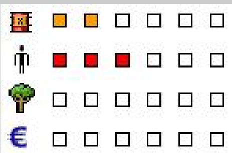
Crisis situation catalysts



21 Ammonia odours in the city

ARIA 34027 – 20/12/2007 - 54 - LANEUVEVILLE-DEVANT-NANCY

23.99 - Fabrication of other mineral, non-metal products



Within a chemical plant producing sodium carbonate, 45 m³ of ammonia-laden water at a concentration of 22 g/l accidentally spilled into the site's 23-ha settling basin. The ammonia cloud (NH_3) that formed by means of vaporisation above the basin did not disperse as a result of unfavourable meteorological conditions (i.e. -4℃, fog, little wind), but instead drifted towards the city of Nancy between 7:30 and 10:00 pm. A pungent odour upset the neighbouring residents of Laneuville-les-Nancy, Jarville-Vandoeuvre and the southern part of the Nancy Metropolitan Area; the police and fire services recorded some 600 phone calls during this period.

The prefecture set up a crisis response unit. Radio messages were broadcast informing the population to remain indoors. Some one hundred fire-fighters were deployed to perform toxicity measurements within the affected zone and inform the local population. The NH_3 concentration, which reached levels of 50 to 60 ppm at the point of toxic release, was measured between 10 and 32 ppm outside the plant (NH_3 Average and Maximum Exposure Limits of 20 and 50 ppm). The state of alert was in effect until 11:30 pm.

The ammonia-laden water stemmed from the liming of ammonium chloride during production of the sodium carbonate. It is a manufacturing by-product typically distilled in order to separate the gaseous NH_3 recycled as part of the process from the saline water transferred into a settling basin prior to discharge into the natural surroundings.

The saline effluents were loaded with impurities (gypsum) that precipitated into the solution intended for distillation and encrusted the devices and piping. The day of the accident, a gypsum crust broke loose when starting up a distillation unit and plugged the suction chamber of the pump assigned to discharge the saline effluent to the settling basin. During the subsequent unscheduled maintenance visit, an operator shut off the distillation columns at their outlet while forgetting to stop the liquid supply line on one of them. After removing crust accumulation on the installation, the column that had gradually filled with undistilled ammonia liquid, due to a liquid load pressure in the column exceeding the vapour pressure, opened on the discharge pump at the basin and the undistilled liquid poured into the basin for 15 min.

Several remedial actions were carried out following the accident, including: improvement of the operating procedure (greater detail added), training of onsite teams in implementing this new procedure, installation of NH_3 sensors at the distillation column outlet, and lowering of the sensor alarm threshold at the level of the settling basin.

Crisis situation catalysts

The event of limited severity presented above relates a wintertime dispersion of malodorous ammonia vapours, yet the concentrations involved were small and the incident produced only a very low level of toxicity. Such a pollution episode however raised great concern among the neighbouring populations, who remained uninformed of the incident for several hours.

Objectively speaking, all crises can be related to two main causes:

- The first one is technical. This cause pertains to the operation of hazardous processes and with it the unavoidable possibility of incidents and accidents. Even when qualified as "residual" after being minimised by appropriate technical and organisational measures, risk can never really be eliminated altogether. This fact relates not only to the potential hazards present within installations, but also to the capacity for human organisations to identify positions on the accident causal chains and to act before basic deficiencies combine and thrust the system onto the accident critical path. Moreover, consequences may be exacerbated by the proximity of vulnerable elements (ARIA 4225, 4998, 12831, 17265, 22375, 23155, 23866, 23936, 26880, 29687, 31312, 32163, 32806, 33669, 33828, 34733, 34828, etc.);
- The second cause is social and pertains to the gap in comprehension by civil society of risk prevention limits and their corresponding rules.

The population's concerns and the crisis that follow an accident are generally all the more intense than the perception of the preliminary risk analysis by prevention actors is quite different from the understanding by civil society of the proven or feared consequences of an accident.

Several factors influence the acuteness with which civil society perceives accidents:

- Misconception or insufficient awareness of the potential for serious accidents, which are often qualified as improbable or only slightly probable by the process actors;
- A sharp contrast between the routine of day-to-day operations and the magnitude of unexpected consequences due to the accident (Mexico City, Bhopal, Enschede, Toulouse, ARIA 4225, 12831, 20493, 33516…), whose geographic extent in some cases crosses national boundaries (Chernobyl, ARIA 17265, 31312, 32679, 33740…);
- The concentration over a short time period of a high number of casualties (Toulouse, ARIA 26002…);
- Exposure to children or the less able-bodied (Seveso dioxins, ARIA 9539, 26002, 31803…), the fear of inducing long-term effects (ARIA 13050, 29977…) or effects for future generations (Seveso, PCB fires…);
- Significant consequences, whether proven or anticipated, immediate or delayed for both the environment (ARIA 12831, 17265, 27146, 30269…) and economy (ERIKA, ARIA 1671…);
- A succession of similar accidents over a short period or implicating the same facility (Tricastin, ARIA 4303, 17265, 23839…);
- Anxiety related to the length of time required to evaluate risks caused by the accident (legionella, dioxins, ARIA 3536, 13050, 15513, 20493, 21990, 23182, 25231, 34893…);
- The Mis-appreciation of materials (PCB, dioxins…), their properties, the relatively unconventional techniques employed (chemical industry, nuclear industry, etc.), the associated risks and accidental mechanisms also contribute to increasing the level of public concern ('Seveso' hazards, legionella…);
- A source of the specific event difficult or impossible to identify quickly: Legionnaire's Disease… (ARIA 26002, 23195, 25551…);
- The ignorance or poor understanding of the set of rules governing risk prevention (ARIA 33516…);
- The lack of confidence in dealing with entities assigned to manage risks (Seveso, ARIA 29977…);
- Difficulties involved in preventing risk and protecting against accident consequences (Toulouse, ARIA 12831, 17265…);
- Long or arduous emergency interventions (ARIA 4998, 13099, 13473, 20436, 21199, 21385, 22375, 23030, 23839, 30103, 31312, 32163, 32215, 32593, 33862, 34893…);
- Difficulties involved in mitigating consequences and in restoring a normal situation (Toulouse);
- An inadequate amount of explicit information on the possible consequences of an accident / incident, delay in generating this information relative to the various points of view expressed in the media or on the Internet (ARIA 26002, 30269…);
- The type and extent of media coverage (Seveso, Toulouse, ARIA 29977…);
- Insufficient information circulated during normal operating periods on prevention limitations.

Without waiting for the serious accident to happen, the occurrence of incidents provides the opportunity for a well-balanced dialogue to take place with the society by means of incorporating both the negative and positive elements, such as anomalies and the set of adopted remedial measures. These exchanges must not be overlooked, given that the opportunities to dialogue with civil society on prevention limits are not very frequent: publication of hazard studies, CLIC (local information and dialogue committees), PPRT (technological risk prevention plans), public consultation and preventive information on external emergency plans.

The immediately released information on incidents taking place within 'SEVESO'-establishments (ARIA 33669, 33828, 33862, 33899, 34281, 34384, 34437, 34499, 34627, 34828...) offers a step in the right direction and may contribute to gradually narrowing the gap in understanding that exists between process actors and the public on the efficiency of prevention measures and their limitations, while promoting the development of shared monitoring.

Additional references (detailed accidents):

- ARIA 29687_nemours_2005 / Ammonia leak within a refrigerated warehouse
- ARIA 23839_chalampe_2002 / Long-lasting cyclohexane leak
- ARIA 13050_amberieux-en-bugey_1998 / Fire in a meat curing plant
- ARIA 4225_la-voulte_1993 / Derailment of a train transporting fuels
- ARIA 3536_jarrie_1992 / Fire/explosion in a production facility using oxygenated water

The accidents whose references are not underlined may be consulted at:

www.aria.developpement-durable.gouv.fr

ARIA 4225 - 13/01/1993 - 07 - LA VOULTE-SUR-RHONE

49.20 - Rail freight transport

Subsequent to an axle failure, 7 rail tanker cars in a convoy of 20 cars derailed; 4 were heavily damaged and spilled their contents. A raging fire then broke out. One railcar suddenly burst open and exploded, with a fireball forming 15 to 20 min later. Streams of ignited fuel spread on the ground and reached the closest dwellings located 20 m away along the lower slope of the rail tracks, creating a succession of explosions in the sewer system. Nearly 1,000 people had to be evacuated during the night within a 600-m safety perimeter. Total damages amounted to over 70 million francs. Some one hundred residents were relocated throughout the pollution cleanup period.

ARIA 4303 - 22/02/1993 - GERMANY - FRANKFURT

21.10 - Manufacturing of basic pharmaceutical products

An operator turned a stirrer back on too late following a facility inspection. A runaway reaction then caused the pressure in a reactor to rise, in addition to discharging (via the safety valves) 2 tonnes of ortho-nitroanisol, 5.5 tonnes of methanol and 0.2 tonnes of soda, plus other emissions. The fallout of chemical products polluted several hectares of soil. Many dysfunctions were recorded during post-accident crisis management. The decontamination steps were valued at 50 million francs. This accident and others that occurred over the ensuing weeks in the company and its subsidiaries led to a major safety inspection programme of chemical facilities across the State of HESSE.

ARIA 12831 - 25/04/1998 - SPAIN - AZNALCOLLAR

08.99 - Other extraction activities

The dyke of a waste storage basin of a pyrite mine broke over a 50-m length after a landslide; as a result, 4 million tonnes of acidic water and 3 million tonnes of sludge laden with Zn, Fe, Cu, Pb and As (0.3 g/l) reached first the RIO AGRIO River and then the GUADIAMAR River, which overflowed by 200 to 300 m over a 20-km section. This toxic flow threatened the Donana National Park, at the periphery of which emergency crews built earthen embankments. In conjunction with this effort, authorities set up dams to confine the bulk of pollution released to the Entremuros Canal (though overflows still flooded neighbouring agricultural areas). A portion of the pollutants did reach the GUADALQUIVIR Delta, some 80 km downstream of the mine and polluted Gulf of Cadiz beaches. The effluent infiltrated into the groundwater, which constitutes the primary water supply resource for the Park and the city of Seville. The waste contaminated 7,000 ha of pastureland and marshland as well as 3,500 ha of farmland, killing 30 tonnes of fish, tens of thousands of birds (geese, storks, etc.), 220 kg of shellfish, frogs, horses, goats… Several individuals were slightly burned by the acidic water while trying to save cattle. Hunting, fishing and water consumption (for irrigation, potable water pumping, etc.) were prohibited for several weeks. The decontamination operation lasted 8 months, and a total of 5 million m³ of sludge and 2 million m³ of excavated farmland were stored in an abandoned mine. 4.5 million m³ of water held in the Entremuros Canal were treated in a waste-water treatment plant and then discharged into the GUADALQUIVIR River. Authorities implemented a water and soil quality monitoring and restoration plan and, in 2004, undertook a programme to replant vegetation on the contaminated banks. The total cost attributed to the disaster was estimated at 240 million Euros, including all drainage and sanitation work, agricultural losses and authority repurchase of contaminated land. The mine was closed for a full 12 months, forcing layoffs of 500 employees; the mine would be shut down definitively in September 2001. The accident was caused by a 1-m landslide of a 600-m² marl plate 14 m thick on top of which the dyke had been positioned. Several expert reports had previously indicated in 1996 the vulnerability of this clayey subsoil and dyke instability. European legislation on managing mining waste was strengthened after this accident and the one at Baia Mare (ARIA reference 17265).

ARIA 17265 - 30/01/2000 - ROMANIA - BAIA MARE

07.29 - Extraction of other nonferrous metal ores

A 25-m long crack formed on the collapsed dyke of a settling basin for mining tailings. A total of 287,500 m³ of effluent laced with cyanide (115 tonnes) and heavy metals (Cu, Zn) spilled, contaminating a 14-hectare sector and polluting the SASAR River. A 40-km "cyanide wave" swept through the LAPUS, SZAMOS and TISZA Rivers before finally reaching the DANUBE. The cyanide concentration rose as high as 50 mg/l in the LAPUS, 2 mg/l in the stretch of the TISZA running through Yugoslavia (on February 12) and 0.05 mg/l in the DANUBE River Delta, some 2,000 km downstream of the Baia Mare site (February 18). Romania, Hungary, Yugoslavia, Bulgaria and the Ukraine were also affected by the accident. High cyanide concentrations were measured in privately-owned wells, and the health of several individuals was adversely affected after ingesting contaminated water. Water consumption and fishing activities were banned in the zone. Wildlife and vegetation were destroyed over an area extending hundreds of kilometres: 1,241 tonnes of dead fish were recovered in Hungary alone, and thousands of dead animals were found (swans, wild ducks, otters, foxes, etc.). The authorities of countries located downstream were quickly informed and could thus take effective preventive measures, including: dam runoff, notifications sent to all water supply utility operators. Dam design flaws (excessive proportions of fines), poor weather conditions (heavy rains and snowmelt resulting in a rise of the basin water level, and a thorough soaking of dam components causing structural weakening) and organisational breakdowns (absence of effluent transfer measurement procedures) were all causes of the accident. The reasons behind the high fish mortality rate could not be clearly established since a very high quantity of bleach might have been used to neutralise the cyanide. After the accident, the basin operator set up a cyanide waste treatment plant, along with a 250,000 m³ holding basin to collect overflow from the settling basin before neutralisation and discharge into the natural environment. The accidents at Baia Mare and Aznalcollar (ARIA file 12831) have led to reinforcing European legislation on mining waste handling. It should be pointed out that major leaks had already been observed on the dyke two months prior to the accident.

ARIA 20493 - 18/06/2001 - 02 - VENIZEL

17.12 - Paper and cardboard production

A fire broke out around 2:50 am in an electrical utility room at a paper mill. Engulfed in the flames, three transformers emptied entirely and a fourth halfway, dispersing 1.5 tonnes of dielectric containing PCB. A prefectural order motivated by a proposal from the inspectorate of hazardous installations prohibited site access as of the very same day and imposed site decontamination work, in addition to commissioning analyses and a detailed risk evaluation. A total of 96 individuals present at the time of the accident (including fire-fighters, employees, 2 journalists and 7 neighbours) had to undergo epidemiological supervision for a full year. The trajectory of smoke led to delimiting a 2.5-km cone-shaped zone for future monitoring and a ban on consuming crop/vegetable production. About one hundred samples of soot, building materials, soils, water and plants revealed the presence of dioxins and furans. Site decontamination work was performed on both the factory buildings and grounds as well as on the two closest dwellings located 250 m away. Moreover, a plan was adopted to eliminate all equipment containing PCB. The gradual reactivation of installations, 15 days after the accident, was subject to prefectural authorisation, which was granted on the basis of receipts for work and successive expert reports submitted by the site operator. The prohibitions relative to exterior land were lifted 25 days later. The quantity of PCB lost equalled approximately 600 kg (of the 2,800 kg initially included), and the quantity of dioxins emitted was 13 kg. The building that caught fire was completely destroyed, with the amount of these damages estimated at 100 million francs. Fire ignition might have been due to a short-circuit or the poor condition of an electrical component. The "transformer fire" scenario had not been investigated in the safety report, and installation drawings had not indicated the precise location of this type of equipment.

ARIA 26002 - 28/11/2003 - 62 - HARNES

20.14 - Manufacturing of other basic organic chemicals

On November 28, 2003, two cases of Legionnaire's Disease were recorded, the first symptoms of which dated back to the beginning of November. The dates of outbreak of the pathology, which were then staggered over time, revealed two distinct waves of contamination with a total of 86 individuals contaminated, aged between 32 and 92 (of whom 18 died). These cases all broke out within a radius of slightly over 10 km around the city of Lens. The DDASS (local Sanitary and Social Affairs Office) conducted environmental investigations at the homes of patients and within several facilities open to the public. At the request of the DRIRE (Regional Agency for the Environment, Research and Industry), all facilities operating cooling towers within the designated zone were asked to adopt measures to identify the eventual presence of legionella and clean their circuits. On October 15, the operator of a chemical installation specialised in alcohols and fatty acids extracted samples whose results revealed a concentration of legionella at a level of 730,000 CFU units/litre. Following a shock treatment using biocides, analyses 15 days later yielded a concentration of less than 100 CFU/litre. On November 20, another inspection announced that the level of 600,000 CFU/litre had been reached. In light of these results, the chemical plant's cooling towers were ordered to be shut down on November 29. As of December 3, the tower circuits were drained and cleaned. Operations resumed on December 22, and a prefectural decree was issued January 2, 2004 mandating the operator to halt all plant activity once again due to the appearance of a second epidemic wave. At the same time, the Prefect commissioned the DRIRE Agency to extend its investigations, notably by inventorying all cooling towers within the neighbouring 53 towns and imposed the shutdown of several installations (automobile washing stations, food processing activities, refrigerated warehousing, etc.), causing layoffs to hundreds of workers for several days. Even though a similarity was detected between the strains extracted from 23 of the patients and those present in the suspected cooling tower at the petrochemical plant, other sources of contamination could not be ruled out. High legionella counts in the lagoons of this same plant necessitated turning off aerators on January 20. This site's revenue loss would amount to several millions of Euros, corresponding to a production downtime of 14 weeks. A prefectural order authorising reactivation of the towers was issued on March 19, 2004, yet the plant would never operate again.

ARIA 29977 - 01/01/2005 - 45 - GIEN

38.11 - Collection of non-hazardous wastes

As part of the mandatory annual analysis of atmospheric emissions, the operator of a household waste incineration plant received on October 8, 2004 the analyses of samples extracted during the month of August, showing: considerable excess of CO (312 and 664 mg/m³ vs. a threshold of 100 mg/m³) on two processing lines (l1 and l2) and in HCl on the l2 line (571 mg/m³ vs. threshold of 50 mg/m³), along with high values of dioxins (29 and 221 ng/m³) on the two lines. Informed of these results on November 8, the local DRIRE Environmental Agency proposed issuing a formal notice to impose compliance with regulatory thresholds in addition to a monthly monitoring campaign instead of annual tests (January 2005 directives), including: tracking of atmospheric emissions and impact of dioxins within a 5-km radius (analyses conducted on milk from adjacent dairy farms, atmospheric fallout). On January 21, the DRIRE Office received the cross-check analyses of discharges conducted during December: no threshold excess on the l1 line, marked excesses of both CO and HCl (513 and 183 mg/m³) on l2, very high dioxin contents on both lines (21 and 308 ng/m³). On the same day, the Agency requested closing l2 altogether (to take effect on January 24), and ultimately suspending this line (order issued on March 16 upon recommendation of the local Hygiene Office). On February 23, the samples taken in January confirmed the facility's malfunctions and the need to shut l2 down: 1,875 mg/m³ of CO and 680 ng/m³ of dioxins above the previous findings. The enhanced atmospheric emissions monitoring programme indicated a return to normal operating conditions on the l1 line. Monitoring was extended out of precaution and oriented towards ensuring food safety, i.e.: dioxin levels found in the soils, plants, eggs, vegetables, grazing lands and fodder. According to the experts (AFSSA, INVS), these results did not reveal any abnormal level of contamination among the various media nor an exaggerated potential health risk for neighbouring populations: in particular, the rate of dioxins in storm water collector pipes was observed to be low in comparison with typical values, the amounts found in milk were compliant with sanitary standards (which equals 3 pg I-TEQ/g of fat, i.e. the value above which milk is recalled from stores), and high concentrations in eggs from family farms attributable, following a field investigation, to local practices. According to the facility operator, an inadequate level of waste preparation (formation of "clusters", accumulation of iron wires) would explain the poor combustion (resulting in the formation of CO and dioxins). The fluidised bed would have gradually deteriorated. The malfunction of smoke exhaust treatment using milk of lime would explain the HCl contents. Works intended to bring operations into compliance and optimise both incinerator furnaces were undertaken. The plant would start up again 3 years hence (January 2008), and at that time the pollutant discharge measures were compliant with regulatory standards.

ARIA 33516 - 06/05/2004 - 88 - EPINAL

86.10 - Hospital activities

Over 800 patients were victims of radiation overdoses during radiotherapy sessions in a hospital during 2004 and 2005. The overexposure to X-rays caused the deaths of 4 patients, and 20 others were very seriously irradiated. According to a report from the nuclear safety authority, these overexposures stemmed from: a computer data entry error in the dosimetry software used during treatment preparation, lack of personnel training in the use of this software, and a poor software user interface. No traceability of operations could be performed. Machine operators were given no user's guide in French adapted to their day-to-day use. 14 individuals filed a suit following the accident: 4 for involuntary manslaughter and 10 for involuntary injuries.

ARIA 34893 - 15/07/2008 - 68 - GEISPITZEN

35.13 - Electricity distribution

A transformer exploded and ignited at 10:15 am, causing projections around the room and an oil spill that partially flowed into the municipal sewage network via gutters. Neighbours notified local fire-fighters, who were on the scene by 10:30 with their standard emergency equipment. A CMIC unit specialised in chemical emergencies had the fire under control 10 min later using a powder extinguisher. Rescue crews noted the presence of oil on the pavement and in a storm drain manhole that was poorly maintained and clogged; since a risk of overflow was feared, another CMIC unit called in as a backup pumped 50 litres of oil into the manhole. As opposed to the first agents onsite at 11:05, the electricity distribution team did not confirm the presence of PCB in the device that had been operating since 1965. Samples were extracted for analysis, the site was cleaned, and the emergency intervention officially ended at 1:10 pm. For precautionary reasons, doctors examined 15 fire-fighters, 2 witnesses and 2 gendarmes, despite showing no symptoms. A blood test was also administered to each of them the next morning. The presence of PCB was finally confirmed upon the Hazardous Installation inspection at 5:30 pm; the oil contained 89 g/kg of PCB, i.e. a concentration greatly in excess of 50 mg/kg and necessitating the decontamination of equipment. The pumped oil and polluted wastes were transferred and isolated at an appropriate site. In order to prevent against additional pollution tied to PCB, a strip of soil hit by oil spatter was scraped 20 cm deep with transfer onto the same site as the excavated earth and transformer. On July 16, the electricity distribution service performed additional sampling of the polluted pavement surfacing before having it covered with a tarp, while informing the IIC Office of the discovery of an unauthorised white verification tag on the transformer (a yellow tag indicates PCB content, a green one content free), dated 2001 indicating the possible presence of PCB. At IIC's request, dioxin analyses of the soot were carried out on July 17. Since the presence of PCB was unknown at the time of the accident (poor communication between fire-fighters and the site operator), the emergency crews did not take all the effective precautions during their performance onsite: cleaning water discharged into the network, crew members not equipped with adapted protective gear, individuals present on the site (police, neighbours) not removed or evacuated accordingly. Once the presence of PCB had been established, all those exposed to fire smoke received proper care and were placed under medical observation.

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.

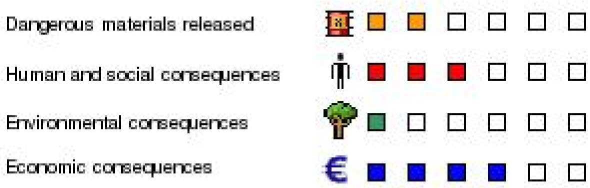
Further to difficulties which stemmed from the attribution of an overall index covering the consequences that are completely different according to the accidents, a new presentation of the European scale of industrial accidents with four indices was proposed. After having completed a large consultation 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 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 financial aspects.

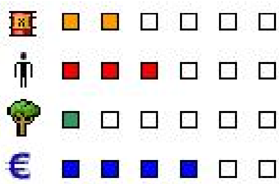
This presentation modifies neither the parameters nor the rating rules of the European scale.

<u>The graphic charter:</u>

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



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



<u>The parameters of the European scale:</u>

Dangerous material released		1	2	3	4	5	6
Q1	Quantity Q of substance actually lost or released in relation to the « Seveso » threshold *	Q < 0,1 %	0,1 % ≤ Q < 1 %	1 % ≤ Q < 10 %	10 % ≤ Q < 100 %	De 1 à 10 fois le seuil	≥ 10 fois le seuil
Q2	Quantity Q of explosive substance having actually participated in the explosion (equivalent in TNT)	Q < 0,1 t	0,1 t ≤ Q < 1 t	1 t ≤ Q < 5 t	5 t ≤ Q < 50 t	50 t ≤ Q < 500 t	Q ≥ 500 t

* Use the higher "Seveso" thresholds. If more than one substance are involved, the higher level should be adopted.

Human and social consequences		1	2	3	4	5	6
H3	Total number of death: including - employees - external rescue personnel - persons from the public	- - - -	1 1 - -	2 – 5 2 – 5 1 -	6 – 19 6 – 19 2 – 5 1	20 – 49 20 – 49 6 – 19 2 – 5	≥ 50 ≥ 50 ≥ 20 ≥ 6
H4	Total number of injured with hospitalisation ≥ 24 h: including - employees - external rescue personnel - persons from the public	1 1 1 -	2 – 5 2 – 5 2 – 5 -	6 – 19 6 – 19 6 – 19 1 – 5	20 – 49 20 – 49 20 – 49 6 – 19	50 – 199 50 – 199 50 – 199 20 – 49	≥ 200 ≥ 200 ≥ 200 ≥ 50
H5	Total number of slightly injured cared for on site with hospitalisation < 24 h : including - employees - external rescue personnel - persons from the public	1 – 5 1 – 5 1 – 5 -	6 – 19 6 – 19 6 – 19 1 – 5	20 – 49 20 – 49 20 – 49 6 – 19	50 – 199 50 – 199 50 – 199 20 – 49	200 – 999 200 – 999 200 – 999 50 – 199	≥ 1000 ≥ 1000 ≥ 1000 ≥ 200
H6	Total number of homeless or unable to work (outbuildings and work tools damaged)	-	1 – 5	6 – 19	20 – 99	100 – 499	≥ 500
H7	Number N of residents evacuated or confined in their home > 2 hours x nbr of hours (persons x hours)	-	N < 500	500 ≤ N < 5 000	5 000 ≤ N < 50 000	50 000 ≤ N < 500 000	N ≥ 500 000
H8	Number N of persons without drinking water, electricity, gas, telephone, public transports > 2 hours x nbr of hours (persons x hours)	-	N < 1 000	1 000 ≤ N < 10 000	10 000 ≤ N < 100 000	100 000 ≤ N < 1 million	N ≥ 1 million
H9	Number N of persons having undergone extended medical supervision (≥ 3 months after the accident)	-	N < 10	10 ≤ N < 50	50 ≤ N < 200	200 ≤ N < 1 000	N ≥ 1 000

Environmental consequences		1	2	3	4	5	6
Env10	Quantity of wild animals killed, injured or rendered unfit for human consumption (t)	Q < 0,1	0,1 ≤ Q < 1	1 ≤ Q < 10	10 ≤ Q < 50	50 ≤ Q < 200	Q ≥ 200
Env11	Proportion P of rare or protected animal or vegetal species destroyed (or eliminated by biotope damage) in the zone of the accident	P < 0,1 %	0,1% ≤ P < 0,5%	0,5 % ≤ P < 2 %	2 % ≤ P < 10 %	10 % ≤ P < 50 %	P ≥ 50 %
Env12	Volume V of water polluted (in m^3) *	V < 1000	1000 ≤ V < 10 000	10 000 ≤ V < 0.1	0.1 Million ≤ V< 1 Million	1 Million ≤ V< 10 Million	V ≥ 10 Million
Env13	Surface area S of soil or underground water surface requiring cleaning or specific decontamination (in ha)	0,1 ≤ S < 0,5	0,5 ≤ S < 2	2 ≤ S < 10	10 ≤ S < 50	50 ≤ S < 200	S ≥ 200
Env14	Length L of water channel requiring cleaning or specific decontamination (in km)	0,1≤ L < 0,5	0,5 ≤ L< 2	2 ≤ L< 10	10 ≤ L < 50	50 ≤ L< 200	L ≥ 200

* The volume is determined with the expression Q/C_{lim} where:
- ✓ Q is the quantity of substance released,
- ✓ C_{lim} is the maximal admissible concentration in the milieu concerned fixed by the European directives in effect.

€ Economic consequences		1	2	3	4	5	6
€15	Property damage in the establishment (C expressed in millions of € - Reference 93)	0,1 ≤ C < 0,5	0,5 ≤ C < 2	2 ≤ C< 10	10 ≤ C< 50	50 ≤ C < 200	C ≥ 200
€16	The establishment 's production losses (C expressed in millions of € - Reference 93)	0,1 ≤ C < 0,5	0,5 ≤ C < 2	2 ≤ C< 10	10 ≤ C< 50	50 ≤ C < 200	C ≥ 200
€17	Property damage or production losses outside the establishment (C expressed in millions of € - Reference 93)	-	0,05 < C < 0,1	0,1 ≤ C < 0,5	0,5 ≤ C < 2	2 ≤ C < 10	C ≥ 10
€18	Cost of cleaning, decontamination, rehabilitation of the environment (C expressed in millions of € - Reference 93)	0,01 ≤ C < 0,05	0,05 ≤ C < 0,2	0,2 ≤ C < 1	1 ≤ C < 5	5 ≤ C < 20	C ≥ 20

GLOSSARY AND ACRONYMS

- ADN : adiponitrile
- AEGL : average and maximum exposure limits
- DWS : drinking water supply
- AFCN : belgian federal agency for nuclear safety
- AFSSA : french food safety agency
- ASN : french nuclear safety authority
- BLEVE : boiling liquid expanding vapour explosion
- BTEX : benzene, toluene, ethyl-benzene et xylene
- CDC : center for disease control
- CEDRE : center of documentation, research and experimentation on accidental water pollution
- CHSCT : comitee for hygiene, safety and working conditions
- CIRE : interregional epidemiology unit
- CLAUS : process for producing sulfur by conversion of hydrogen sulfide
- CMIC : chemical emergency squad
- COD : chemical oxygen demand
- COV : volatile organic compounds
- CPCU : Paris municipal heating company
- DDSV : departmental veterinary directorate
- DICT : formal start of works notification
- DNTCBB : dinitro 2-6 tertiobutyl 4 chlorobenzene
- DREAL : regional department for environment, town planning and housing
- DRIRE : regional directorate for industry, research and the envionment
- ERPG : emergency response planning guidelines
- ESP : pressure equipment
- ETARE plan : a plan established by each departemental fire services unit for installations where an existing risk cannot be mitigated through conventional means of intervention (listed facilities)
- FCC : fluid catalytic cracking
- HAP : PAH (poluaromatic hydrocarbon)
- HCl : hydrogene chloride
- HDS : hydrodesulfurization
- ICPE : classified facilities for environmental protection
- InVS : sanitary survey institute
- IPCC : intergovernmental panel on climate change
- IPPC : integrated pollution prevention and control

- LEL : lower explosive limit
- MIC : methyl isocyanate
- MTBE : methylterbutylether
- PAH : polycyclic aromatic hydrocarbon
- PCB : polychlorinated biphenyl
- PCT : polychlorinated terphenyl
- POI : internal emergency plan
- PPRT : technological risk prevention plan
- SCOT : process for treating Claus units tail gas
- SDIS : french departmental fire service
- SG : spheroidal graphite
- SIDPC : Interministerial civi defence and protection department
- UVCE : unconfined vapour cloud explosion
- VCE : vapour cloud explosion

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