Links between operating experience feedback of industrial accidents and nuclear safety

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Abstract:
Since 1992, the bureau for analysis of industrial risks and pollutions (BARPI) collects, analyzes and publishes information on industrial accidents. The ARIA database lists over 40,000 accidents or incidents, most of which occurred in French classified facilities (ICPE). This paper describes the process of selection, characterization and review of these accidents, as well as the following consultation with industry trade groups.

It is essential to publicize widely the lessons learned from analyzing industrial accidents. To this end, a website gives free access to the accidents summaries, detailed sheets, studies, etc. to professionals and the general public. In addition, the accidents descriptions and characteristics serve as inputs to new regulation projects or risk analyses.

Finally, the question of the links between operating experience feedback of industrial accidents and nuclear safety is explored: if the rigorous and well-documented methods of experience feedback in the nuclear field certainly set an example for other activities, nuclear safety can also benefit from inputs coming from the vast diversity of accidents arisen into industrial facilities. An example, based on accidents recorded in the ARIA database, is developed.

1 INTRODUCTION

Since 1992, the bureau for analysis of industrial risks and pollutions (Bureau d’Analyse des Risques et Pollutions Industriels – BARPI) of the French Ministry of Sustainable Development collects, analyzes and publishes information on industrial accidents. Attached to the Directorate General for Risk Prevention (DGPR), a team of 15 persons located in Lyon continuously records accidents occurring in all fields of technological risks. Some incidents – that is events without release of hazardous substances and without human, environmental or economical consequences within the meaning of the European scale of industrial accidents – are also taken into account, for example when they arise in Seveso plants, which are submitted to a tighter control than the other, less risky, industrial facilities.

These accidents, recorded in the ARIA database, occurred mainly in French classified facilities (ICPE). Nuclear facilities, whose control is performed by the independent nuclear safety authority (Autorité de sûreté nucléaire – ASN), are also subject to accidents, and of course to many more incidents used as inputs for improving nuclear safety through operational experience feedback. These incidents are only rarely recorded in the ARIA database, both because they are often without human, environmental or economical consequences and because they are already closely followed and analyzed by ASN and IRSN.

Nevertheless, industrial accidents and nuclear incidents have some common grounds, and the exchange of views between the actors of industrial risk prevention and nuclear safety is likely to promote mutual enrichment.
2 FROM THE INDUSTRIAL ACCIDENT TO THE EXPERIENCE FEEDBACK

2.1 The ARIA database and the ARIA website

2.1.1 The ARIA database

The ARIA (Analyse, Research and Information on Accidents) database lists the accidental events which have, or could have damaged health or public safety, agriculture, nature or the environment. These events are mainly caused by industrial or agricultural facilities that have been or are likely to be classified as hazardous, but also by transportation of hazardous materials and other events with lessons that also apply in this context.

With all activities taken together, the database lists over 40,000 accidents and incidents, of which about 34,000 in France. Foreign accidents are listed mainly due to the seriousness of their consequences or their value in terms of experience feedback.

Originately, the scope of the database embraced essentially:
- the accidents arisen within sites submitted to the ICPE regulation (Classified Installations for the Protection of the Environnement),
- the transport of dangerous goods,
- the accidental water pollutions.

Additionally, some accidents occurred in other types of facilities were also taken into account when they included transposable lessons. This applies to the accidents, incidents and accidental pollutions arisen in nuclear installations (submitted to the INB regulation – Basic Nuclear Installations).

Following the creation of the Directorate General for Risk Prevention (DGPR) in July 2008, this initial scope was expanded to the following areas: hydraulic dams, mines and quarries, pressure equipments and natural gas distribution.

Figure 1: English homepage of the ARIA website
2.1.2 The ARIA website

Transparency on industrial safety is a justifiable requirement of our society. Therefore, since June 2001, professionals and the general public have access to the results of analysis of technological accidents on the website www.aria.developpement-durable.gouv.fr. The main sections of the website are presented in French and in English.

To encourage sharing of information, the accidents are presented anonymously (no mention of the operator’s or plant’s name) in all publications related to ARIA.

Two hundred detailed and illustrated technical reports present accidents selected for their particular interest. Numerous analyses grouped by technical subjects or by activities are also available. The section dedicated to the technical recommendations develops various topics: chemical, pyrotechnics, surface treatment, silos, fire license, waste treatment, handling... A multicriteria research engine enables to reach information about accidents arisen in France or abroad.

2.2 Collecting information on industrial accidents

2.2.1 Accidents selection

The BARPI’s mission implies to daily monitor the information available on industrial accidents and pollutions. Multiple channels are used:
- daily reports issued by ministries,
- reports of fire and rescue services,
- environmental newsletters,
- press alerts,
- etc.

![Figure 2: Example of report of fire and rescue services](image)
In addition, the BARPI is frequently informed of accidents or incidents by classified facilities inspectorate. The information thus obtained often proves very valuable, because of the inspectors’ privileged access to data and facilities. In many cases, mechanisms for mandatory reporting of accidents and / or incidents are in place, facilitating the gathering of information.

Most accidents are recorded in the days or weeks following the events. However, information or reports on past accidents or incidents, sometimes even several decades old, are regularly brought to the knowledge of the BARPI. Moreover, the initial recording of an accident is completed or corrected whenever additional information is available.

2.2.2 Data input

Once acquired, the information gathered about an accident is entered into the ARIA database. A custom-made interface is used, composed of a series of input forms concerning:

1. sources of information
2. site characteristics,
3. type of event and substances involved,
4. consequences,
5. intervention and mitigation measures,
6. causes and circumstances,
7. actions taken – administrative impacts and criminal proceedings,
8. actions taken – technical aspects.

A photomanager is also implemented.

Over 1,500 input fields (both numeric and text) and check boxes enable high accuracy in the recording process.

At last, a summary is written in order to synthetize all trustworthy or assumed informations on the accident.

2.2.3 Accident review

The accident is then reviewed by the BARPI’s agent in charge of the industrial activity involved. The different sources of information are cross-checked and as far as possible more information is gathered from the press and the control or investigation authorities.
2.2.4 Consultations

Before the accidents summaries are put online, they are submitted to both classified installations inspectorate and the relevant industry trade groups. This step offers the local actors an opportunity to point out discrepancies and lacks in the accidents descriptions. Moreover, these consultations often lead to new accidents being brought to the BARPI’s attention.

Working with the industry trade groups offers two benefits:
- it gives them a chance to confront their version of facts with that of the administration;
- it involves them in the process of experience feedback and helps to build links to explore partnerships in the field of risk prevention.

2.2.5 Online posting

After a final round of proofreading, the accidents summaries are finally put on line, approximately 4 months after the events. The most significant accidents are grouped and commented upon in an article issued every two months in the specialized press.

2.3 Operating experience feedback of industrial accidents

2.3.1 Produce analyses to inform decision-making

Excerpts and analyses of the ARIA database are widely used to inform decision-making, both in the regulation process and when danger analyses are required.

When the redaction of a new regulation – or the revision of an old one – is engaged, an accidentology analysis is produced by the BARPI and transmitted to the office in charge of regulation writing. This is highly appreciated as it allows to compare the proposed safety requirements with the number and consequences of accidents that have occurred in the sector concerned.

Moreover, operators often use the ARIA website to gather information on the accidents occurred specifically in their sector or facilities to these they intend to build, as required in some authorisation procedures.

2.3.2 Share and make use of experience feedback

It is essential to publicize widely the lessons learned from analyzing industrial accidents and incidents in order to develop measures for preventing technological risks. In this respect, both positive and negative experience should be shared and exploited more effectively so that the safety of facilities can be continuously improved. Better sharing and use of experience feedback makes it possible to reduce costs and achieve faster progress. The information already available offers attractive prospects for progress in preventing risks.

In this purpose, the BARPI publishes, in addition to the 40,000 accidents summaries and the 200 detailed sheets online, different types of transverse analyses, amongst which:
- an annual inventory of technological accidents in France, detailing the types of accidents, the activities involved, the consequences, the circumstances and the primary causes;
- dozens of studies featuring accident data analyses and recommendations presented by topic (ammonia-based refrigeration, chlorine, hydrogen, pyrotechnic substances…) or by sector of industrial activity (waste treatment, surface treatment, fine chemistry, warehouses, fuel depots…);
- a CD-ROM collection available upon request containing, among other things, proceedings from the latest seminars organised on the topic of industrial accidents within the framework of the IMPEL network of European inspectorates.
Unlike other technological accidents databases in Europe, the publications on the ARIA site are provided free of charge.

Such information and lessons are intended for all actors involved in risk prevention efforts:
- industries, which conduct process safety studies and operate installations,
- employees, who implement processes on a daily basis,
- experts and researchers, who evaluate and model the inherent risks,
- classified facilities inspectorate, which proposes regulations and carries out inspections,
- municipal councils, in order to understand the risks and issue judgments as part of official procedures,
- elected officials and administrative agencies responsible for preventive information and urban planning issues,
- emergency services, to implement the emergency response plans or conduct drills,
- members of environmental commissions,
- training organisations,
- associations, local residents.

3 OPERATING EXPERIENCE FEEDBACK IN INDUSTRIAL AND NUCLEAR FACILITIES

3.1 A nuclear exception?

3.1.1 A specific context

The technical and administrative context in which nuclear facilities operate is specific in many ways: in particular, they are submitted to specific regulations, and often controlled by bodies separate from those controlling industrial facilities. Such is the case in France, where the independent Nuclear Safety Authority (ASN) is in charge of regulating nuclear safety and radiation protection. ASN records all nuclear events in its own internal database, and ensures communication on those rated level 1 or above on the INES scale.

For this reason, incidents arisen inside nuclear facilities are most often not recorded in the ARIA database (whereas incidents arisen inside Seveso plants are recorded). There are exceptions, justified by the transferability of lessons learnt from the incident.
3.1.2 Peculiarities of nuclear safety and nuclear facilities

The analysis, diffusion and exploitation of experience feedback is a major component of nuclear safety. The reporting (both internal and regulatory) and analyzing methods involved have been intensified way beyond the level most other fields have achieved, and the mechanisms of operating experience feedback inside and between nuclear facilities often set an example to follow for other industrial activities, such as Seveso plants or hydroelectric dams.

Furthermore, the incidents dreaded are to a large extent specific to the nuclear field: criticality is a good example; cooling issues are also to be put in relation with the residual heat associated with nuclear reactions. And the vast majority of events arisen on nuclear power plants are only transferable to other NPPs – and sometimes only to those of the same technology – but not to other industrial facilities.

3.1.3 And yet many similarities

Things are of course different for other nuclear facilities. For example, the fuel cycle facilities use many chemicals and chemical processes that are also used by chemical industries.

Moreover, the problems resulting from the ageing of equipments affect both heavy and nuclear industry. They gave way in France, following a succession of accidents that occurred towards the beginning of 2009 in both the chemical and oil industries, as well as in the pipeline transport of hazardous materials, to a vast action plan intended to limit the risks tied to equipment ageing, launched at the beginning of 2010. This led to numerous exchanges between DGPR and ASN.

3.1.4 A few examples

Risks involving hydrogen concern a large number of activities that use or produce the gas: chemical, pharmaceutical, oil refining or transport industries, as well as metallurgy, metal processing and recovery or sanitation for which the risks are even more pernicious as hydrogen is often generated accidentally. Nuclear facilities also use hydrogen, of course, and are exposed to its risks. The BARPI has published an analysis of accidents involving hydrogen, based on a sample of 215 events, 5 of which concerning nuclear facilities.

![Table]

<table>
<thead>
<tr>
<th>Activities</th>
<th>Nb of cases</th>
<th>%</th>
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</thead>
<tbody>
<tr>
<td>Chemical sector</td>
<td>84</td>
<td>39</td>
</tr>
<tr>
<td>Refining / petrochemical industry*</td>
<td>47</td>
<td>22</td>
</tr>
<tr>
<td>Transport, packaging and storage</td>
<td>35</td>
<td>16</td>
</tr>
<tr>
<td>Metallurgy / metal works</td>
<td>17</td>
<td>7.9</td>
</tr>
<tr>
<td>Waste treatment / recycling</td>
<td>8</td>
<td>3.7</td>
</tr>
<tr>
<td>Nuclear industry</td>
<td>5</td>
<td>2.3</td>
</tr>
</tbody>
</table>

* excluding transport, packaging and storage

Figure 5: Repartition of accidents involving hydrogen into the ARIA database

Another example is ammonia, a gas used by nuclear power plants as an ingredient in the onsite production of monochloramine. Ammonia is involved in numerous accidents: at least 900 entries can be found in the ARIA database. Despite the diversity of industrial activities involved (e.g. refrigeration), part of the lessons learnt from these accidents (related to the toxic risk) are transferable to NPPs.

On 12 September 2011, an explosion occurred in the melting furnace of the Centraco facility in the South of France. It was soon clear that the amount of radioactivity involved was low and that no radiological consequences for local populations and the environment was to be feared. The human consequences, on the other hand, were heavy with one employee dead...
and four others injured. This led to a beneficial cooperation between ASN and DGPR, as similar accidents have been recorded and analyzed by the BARPI over the last twenty years, the latter of which occurred on 25 June 2011 in Feurs (42), leading to the death of two employees.

3.2 Using the ARIA database to improve experience feedback

The points developed above, while reminding that the methods of operational experience feedback of nuclear activities may be seen as a sort of paradigm, tend to show that there is also room, in the sphere of nuclear safety, for inputs coming from the analysis of industrial accidents.

The following sections detail an example. Starting from a rather trivial accident, we will see how queries from ARIA allow to extend the scope of an experience feedback analysis. The complete summaries of the discussed accidents can be found in annexe (excerpts are inserted below).

3.2.1 Fire in a container of radioactive waste – ARIA 33181

On 4 June 2007, a fire broke out in a container holding 90 bags of radioactive waste located in the waste packaging workshop of the uranium conversion site COMURHEX Pierrelatte. The fire was extinguished by the plant firefighters in 45 minutes. The most likely origin of the event is an exothermic chemical reaction between incompatible products. The operator occasionally uses cellulose-free wipes impregnated with 58 % nitric acid. Nitric acid is an oxidizer which, when mixed with combustible material, may trigger fires.

This accident is interesting because it is repetitive: solely on the Pierrelatte site, at least two similar accidents happened in 2006 in the premises of INB n°105. The second incident was classified at the level 1 on the INES scale.

Let us now suppose you are somehow in charge of nuclear safety, risk prevention or fire prevention in the nuclear field, and you want to warn the other operators against the risk of duplicating this accident. What you will want to do is to characterize the accident in such a way that you can phrase your warnings in generic terms which may apply to different – but similar – situations in other facilities.

To this end, three queries were successively run on the ARIA database, with following parameters:
- Fire = yes & Substance involved = nitric acid: 27 accidents found, amongst which ARIA 33181 and ARIA 36899;
- Fire = yes & Uncontrolled chemical reaction = yes & Accident summary contains ‘waste’: 38 accidents found, amongst which ARIA 33181, ARIA 36899 and ARIA 30679;
- Fire = yes & Uncontrolled chemical reaction = yes & Substances poorly stored or conditioned = yes: 26 accidents found, amongst which ARIA 33181, ARIA 36899, ARIA 30679 and ARIA 5608.

3.2.2 ARIA 33181 is a fire involving nitric acid…

… so is ARIA 36899:

On 6 November 1990, upon shift start, an emulsion composed of a mix of water, nitric acid, nitroglycerin, nitroglycol, etc. was found ablaze. The fire was put out by an employee using an extinguisher. The day before, a technician had recovered the emulsion and placed it into a pitcher thinking it could wait until the next day. The normal procedure called for conducting an analysis by the laboratory, which would then make a decision regarding destruction. The wastes reacted when placed in contact with air, thus triggering the blaze.
This accident highlights both the importance to properly train employees towards the risks of chemically unstable waste, and the caution to observe in case of a sudden change in the amount or characteristics of waste generated.

3.2.3 ARIA 33181 is a fire which broke out amongst contaminated waste…

… so is ARIA 30769:

On 8 June 2005, a fire kindled seven wooden pallets and plastic packaging containers of chemicals deposited in a waste storage area of a pharmaceutical plant. The fire was mastered by the plant firefighters. After examination of the premises, no trace of physical initiator that may have provided sufficient energy for the combustion was recovered. It is assumed that the origin of the fire is linked to the presence of reagents such as hydrides whose decomposition releases hydrogen.

This accident illustrates that, in addition to nitric acid, other chemical substances might cause fires amongst contaminated waste, even without any external heat source around. In this case, hydrides were involved.

3.2.4 ARIA 33181 results of an uncontrolled chemical reaction between substances poorly stored or conditioned…

… so is ARIA 5608:

On 22 June 1985, a fire broke out in a bagging workshop at the base of a row of pallets containing fungicide. The plant firefighters put out the blaze with foam in 30 minutes. The use of microperforated bags, which replaced hermetic paper bags just a few days earlier, was determined to be the cause of the fire. These microperforated bags could lead to sufficiently high temperatures resulting in the self-ignition (100°C) of the carbon sulphide, produced from the degradation of manganese dithiocarbamate.

This accident shows that the type of packaging is also a relevant parameter in risk analyses related to unstable chemical substances or waste. In that particular case, the simple fact of replacing paper bags with microperforated bags directly led to the accident, whereas no other change of the process or substances involved was made.

![Figure 6: Example of ARIA query](image)
3.2.5 Is this example purely hypothetical?

No. This example was chosen precisely because such a “warning” has indeed been issued: on 17 January 2007, ASN sent a letter to operators of nuclear installations other than NPPs asking them to assess the risk of fires involving nitric acid – acting as an oxidizer – and combustibles on their facilities.

The analysis of the three accidents selected and introduced above in sections 3.2.2 to 3.2.4, all arisen in chemical, non nuclear, facilities, considerably widens the scope of potential situations to analyze, including:
- sudden changes in the amount or characteristics of waste generated,
- other chemical substances involved, such as hydrides,
- type of packaging used,
- and so on…

These new elements could help to conduct risk analyses by suggesting alternative ways for the fire to start.

4 CONCLUSION

The viewpoints of the BARPI and the organisms involved in nuclear safety (authorities, technical safety organisations…) towards operating experience feedback are obviously quite different: when the BARPI records annually about 1,000 accidents occurred in French classified facilities, ASN and IRSN analyze each year approximately 1,000 incidents arisen in French nuclear installations (INB).

Moreover, the distinct reglementary contexts, the separate inspection bodies, and the peculiarities of nuclear safety and nuclear facilities make it difficult to confront the feedbacks of industrial and nuclear events.

Nevertheless, industrial accidents and nuclear incidents have some common grounds, and the two fields can hopefully benefit from each other. In particular, operating experience feedback from nuclear installations other than NPPs can surely benefit from the vast diversity of accidents arisen into industrial facilities. That is at least what is suggested by the example developed above.
5 ANNEXE – ACCIDENT SUMMARIES

ARIA 33181 - 04/06/2007 - 26 - PIERRELATTE
Within a nuclear fuel production plant, a fire broke out in a container holding 90 bags of radioactive waste located in the waste packaging workshop. The plant’s emergency plan was activated, the staff was confined. The plant firefighters extinguished the fire 45 minutes after detection using a water lance. 34 employees confined near the fire, suspected to have inhaled smoke, underwent radiotoxicology analysis, which showed no contamination. The operator issued a press release. With no external heat source involved, the most likely origin of the event is an exothermic chemical reaction between incompatible products. The operator occasionally uses cellulose-free wipes impregnated with 58 % nitric acid. Nitric acid is an oxidizer which, when mixed with combustible material, may trigger fires. However, the nature of products involved is not identified with certainty.

The classified facilities inspectorate asked the operator to set up an enhanced surveillance of technological waste, to assess the risk of spontaneous combustion of waste during transport and storage and take actions accordingly, to study and implement actions to prevent the mixing of oxidizers and combustibles in solid waste, to clarify the nature of permitted and prohibited materials in waste and the associated controls. The operator must also assess the potential consequences of the rupture because of the heat of pipes of anhydrous hydrofluoric acid located 2-3 m above the container, check their integrity after the fire and remove the storage of combustible materials under the pipes of hazardous substances. Control of the fire by the plant firefighters and efficient crisis management are emphasized by the inspectors.

ARIA 36899 - 06/11/1990 - NC - NC
Upon starting his shift, a nitration specialist noticed flames at the door leading to the workshop. He immediately began fighting the fire using an extinguisher and was able to put out the blaze. The day before, a technician had recovered inside the acid tank separator situated at the beginning of the residual acid pipeline leading to the nitrogen removal agent, an emulsion composed of a mix of water, nitric acid, nitroglycerin, nitroglycol, etc. that he placed into a pitcher along with a bucket made of ebonite rubber.

Unable to immediately contact the Production Manager to show him the sample, he took the initiative to temporarily store it, thinking that its destruction could wait until the next day. The normal procedure called for conducting an analysis by the laboratory, which would then make a decision regarding destruction. The wastes reacted when placed in contact with air, thus triggering the blaze.

The investigation revealed that the large quantity of waste collected originated from a rather rapid cooling of the residual acid tank over the four days of downtime around the first of November, given that the space heater had been removed for repairs.

The operator reset the heating system and acid tank temperature regulation system, in addition to carrying out a safety study for the waste extraction station inside the separator and offering a refresher training course to staff members assigned to handle wastes.

ARIA 30679 - 08/06/2005 - 69 - NEUVILLE-SUR-SAONE
At 4:45 pm, a fire kindled seven wooden pallets and plastic packaging containers of chemicals deposited in a waste storage area of a pharmaceutical plant. These wastes were awaiting shipment to external treatment facilities. Black smoke was driven by a strong north wind towards the SAONE. The internal emergency plan was triggered. Small explosions were reported by the first responders. At 4:50, the fire was mastered by the plant firefighters. At 5 pm, the emergency plan was lifted, the area remained under surveillance for several hours.

After examination of the premises, no trace of physical initiator that may have provided sufficient energy for the combustion was recovered. It is assumed that the origin of the fire is linked to the presence of reagents such as hydrides whose decomposition releases hydrogen. This hypothesis seems all the more plausible that the instability of hydrides with temperature is demonstrated even when they are stabilized by an alkaline medium.

The procedure for the collection, storage and processing of contaminated packaging was revised and supplemented by a comprehensive list of reagents to be treated with care. Instructions for waste management were remitted to all employees and subcontractors. Finally, general information was made on the importance of observing instructions for sorting and waste management and the potential consequences of such accidents.

The experience feedback from the accident was sent to the other sites of the group.

ARIA 5608 - 22/06/1985 - 38 - LE PONT-DE-CLAIX
A fire broke out in a bagging workshop at the base of a row of pallets containing fungicide (manganese dithiocarbamate produced from carbon sulphide, ethylene diamine and manganese salt). The plant firefighters fought the blaze with foam to avoid sending polluted water into the sewer system. It took 30 minutes to bring the fire under control. As the stock of fungicide tended to burst back into flames, it was removed in metal bins and kept under surveillance.

The use of microperforated bags, which replaced hermetic paper bags just a few days earlier, was determined to be the cause of the fire. These microperforated bags could lead to sufficiently high temperatures resulting in the self-ignition (100°C) of the carbon sulphide, produced from the degradation of manganese dithiocarbamate. Reoxygenation of the mass contained in the bag facilitated by the microperforations and better filling of the bags (greater settlement) explains the phenomenon that lead to the fire.