Safety practice

A review on Toulouse accident trials: some lessons to learn despite uncertainty on direct causes

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Introduction

A number of separate inquiries were carried out in the aftermath of the Toulouse disaster to identify the generic lessons to learn. All provided findings, recommendations and lessons in relation to some of the direct and root causes of the disaster. Some of these findings resulted in changes to both the French law on industrial risk prevention (Loi Bachelot 2003-699) and to European legislation, firstly in 2003 with a change of classification criteria for ammonium nitrate fertiliser and off-specification materials, and later to some extent in Seveso III in 2013.

During the third trial in 2017 — more than sixteen years after the disaster — to determine criminal responsibility, the direct causes were still being challenged by the Total group lawyers and other experts. These issues became the major debating points during the three trials. As the prosecution's main scenario remains contested and uncertainty on direct causes remains, this could raise doubts on the relevance of the learning lessons process that led to changes in French and European legislation.

One or several accident scenarios? What (potentially) happened?

At 10.17 a.m. on 21 September 2001 a severe explosion occurred at the AZF plant in Toulouse, France resulting in extensive damage. There were 30 fatalities to workers and nearby residents, with an estimated 10,000 people receiving injuries and 14,000 suffering post-traumatic acute stress. Approximately 27,000 houses and flats in the city were damaged[1,2].

Warehouse No. 221 stored around 400 tons of downgraded, off-specification ammonium nitrate (AN) based products. The explosive properties varied as some were fertilizer grades and some were technical grades which were dedicated to explosive purpose (AN mixed with fuel oil). According to the degree of AN concentration and other parameters, there remained a latent risk of explosion. This material had been carried in buckets from various workshops to an inlet area by three subcontractors and then taken by transport equipment into the warehouse. The stored material was periodically removed and transferred to another plant to be recycled to produce complex fertilizers. The day before the explosion, 15 to 20 tons of AN with an additive in qualification phase was brought into the warehouse. On the morning of the explosion, products derived from the packaging and the production workshops were also transferred into the building. The last amount of material from another storage zone was transferred less than 30 minutes before the explosion.

The main assumption of the police and prosecutor was that the plant management failed in its safety management of the waste of AN-based products. It is assumed that waste containing chlorinated compounds manufactured in another unit of the plant was mixed by chance with waste from ammonium nitrate-based materials. This error would have been committed by subcontractors in charge of waste management who lacked knowledge of hazards associated with AN-based materials.

Although this chronology could satisfy the prosecutor and process safety experts for deeper investigation into the direct causes of this scenario, several other "out of the scope" events occurred. These events triggered other assumptions and alternative scenarios were published in newspapers, thereby increasing the controversy.

Among them, some witnesses mentioned that they heard two distinct explosions which was later proved by acoustic scientists. This result could challenge the belief that the triggering factor was the AN waste storage explosion; some experts have investigated the possibility that a gas leak on one of the plants was the first explosion triggering a second, larger-scale one. Some witnesses mentioned electrical disturbances before the explosion, which led some external experts to the assumption of an underground electrical arc connected to an Electricité de France transformer nearby. Another theory considered the fact that the underground soil was contaminated by former chemical and military activities such as nitrocellulose. Several victims and analysts claimed that these alternative scenarios should have received more attention and investigation to provide evidence, analysis and help to define the truth during the trials.

The trials — controversy and uncertainty for direct causes

First of all, it is important to recall some elements of the socio-political context — the disaster occurred ten days after the 9/11 Twin Towers terrorist attack. The prosecutor in charge, Michel Bréard declared to the media on 24 September that "*it is 99% probability an accident*". This early statement generated many doubts on the justice litigation objectivity as 65% of the inhabitants of Toulouse in August 2002 still thought that it was an attack.

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Dates	Judicial steps
2001/09/21	The explosion at AZF plant in Toulouse leads to a disaster.
2002/06/14	11 employees (among them the director of the plant) and 2 subcontractors receive preliminary examination (indictment).
2006/05/11	Final report by the experts for the judicial inquiry is based on the scenario of a chemical accident due to an incompatible reaction between waste from chlorinated compounds and waste from off-specification ammonium nitrate-based fertiliser and technical grade. Some chemical tests have shown that a mixture between AN and DCCNa (SDIC, sodium dichloroisocyanurate) or AN and ATCC (trichloroisocyanurate acid) is strongly incompatible. In presence of small moisture content, the reaction is violent and starts as soon as the products come into contact, even at temperatures close to ambient temperature. This reaction involves the production of a very unstable substance, trichloramine NCl3, which is very sensitive and can explode. Other scenarios were investigated, such as terrorist attack or malicious act, but excluded. Sixteen causes were investigated by the prosecutor and twelve were discussed during the trial; some others were not considered (though they were mentioned in newspapers).
2009/02/22	Beginning of first trial, lasting four months, at the Criminal Court in Toulouse. The case is made of 120 chapters and the trial was filmed. Several victims testified. Several chemical experts testified either about stability or instability of AN. Other experts in explosions, including acoustic specialists for the two explosion scenario, and electrical specialists for the underground electrical arc scenario also testified.
2009/11/19	Decision of the Criminal Court is a general acquittal for all parties in indictment due to remaining doubts on the evidence. The prosecutor and victims request an appeal with judgment by the court of appeal.
2011/11/03	Beginning of the second trial, also lasting four months, at the Court of Appeal in Toulouse. The prosecutor indicated again a failure to manage the AN and chlorine off-specification waste and a link between this failure, the fault and the damages.
2012/09/24	With similar findings, the sentence is however different as they considered other origins of the explosion that had been excluded previously. The experiments showed some explosion initiation delays were compatible with the chronology. The decision of the appeal court was summarised in a report of 682 pages. The former plant director was condemned for a lack of adequate training of subcontractors on hazards and lack of coordination and oversight. He was sentenced to a three-year prison sentence and fined €45,000. The Grande Paroisse subsidiary was condemned for lack of cross-control of decisions made by the plant director and received the maximum fine of €225,000. The company and the director requested to appeal at the Supreme Court.
2015/01/13	The Supreme Court overturned the appeal court sentence for procedural reasons — due to lack of partiality of one judge that had helped the victims association (she had requested not to be part of the judges when she was ordered but failed to be replaced) and lack of evidence.
2017/01/24	Beginning of the third trial at the Court of Appeal, but this time the appeal was heard in Paris. The trial lasted four months again but some other experts also testified. The prosecutor finally abandoned the chemical assumption that could not be 100% proved, but chose to defend the law strategy considering that all conditions were there for an accident waiting to happen with failures in professional good practices, careful approaches and lack of compliance with the law. In the end, the three options for the court were either to condemn, to acquit or to seek further information (investigations) on other scenarios.
2017/10/30	Judgment of the Court of Appeal handed the former director of the AZF plant a suspended prison sentence of 15 months and a €10,000 fine. The Grande Paroisse company were ordered to pay the maximum fine of €225,000 euros. The Total group, however, was acquitted. The lawyers of the Total Group subsidiary still claimed that it would require an appeal to the Supreme Court, as did several victims groups who requested more investigations, as the verdict was reached with a different law article and principle by indirect or default causality. Court renounced to sentence for a 100% certainty on the causality between management faults and homicides.
...	Fourth trial expected?

Table 1 – The judicial steps

Secondly, a key aspect is the choice of the French legal system framework in which the victims (2700 claimed to be and asked for litigation) required the inquiry and judgment to be performed. Several groups of victims and their lawyers asked for criminal law litigation in order to be able to potentially sentence the key responsible persons in charge and the company (Grande Paroisse a subsidiary of TotaFinaElf group). However, to obtain the guilty verdict and sentence those responsible to jail for manslaughter, the prosecution had to demonstrate proof beyond doubt. Therefore, the company's defence goal was to challenge the 100% certainty thesis by raising doubts on some causality evidence and on the exhaustiveness of the investigation with regards to other assumptions and scenarios. If the victims had chosen to seek financial compensation through civil law litigation, the most probable scenario would likely have been enough.

Among the criticism by some contributors and observers (e.g. the web blog of Daniel Dissy), is to point out that the judges know the law, not the chemistry; and the judicial truth is not the scientific truth. In addition, Hubert Seillan, lawyer and former director of the Préventique magazine (one of the magazines that published some articles on alternative scenarios) noted in 2017 that the inquiry to prove one theory with 100% certainty within criminal law often dominates the contradictory inquiry on several alternative scenarios. Another criticism is the use of the indirect reasoning of cause by default of others; that is threatened by lack of evidence on causality on the assumed scenario and on the exhaustiveness of alternative scenarios identification for which plausibility should be assessed too[3]. In addition, Total lawyers but also other experts have criticised the realism of the tests made by the experts from the justice to show the chemical reaction that lead to the explosion after mixing off-specification AN and chlorinated compounds. Several victims considered that the company lawyer's role was to discuss evidence, raise doubts and bring other "crazy assumptions" (Le Monde journal, 2017, 31st October).

As a temporary conclusion established more than sixteen years after the accident, no consensus on evidence and no scientific truth emerged from the trials and the controversy and uncertainty on direct causes remains.

Some established root causes of the disaster

However, all the investigations, commissions and hearings led to a clear global understanding that the explosion of off-specification AN was not prevented and turned into disaster due to several failures in risk assessment, management,

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governance, control and regulation (e.g. with failures at several levels of the sociotechnical system[1]).

Among them, one of the striking lessons is that the accident scenario was not included in the safety case report of a Seveso plant. This failure of risk analysis occurred also at Buncefield, thus questioning abilities of classic risk analysis in process safety and the methods used to identify relevant risks and "atypical" scenarios[4].

In fact, there were ambiguities on the chemical behavior of some ammonium nitrate related compounds, and there are still uncertainties on its explosive property in some conditions and was classified as an "occasional explosive"[5]. This contributing factor is a root cause despite the long history of accidents that warned the industrial community about its inherent risks and its sensitivity in some conditions. One can mention Oppau disaster in 1921 in Germany, Texas city in the USA and Brest in France in 1947, and even after Toulouse, in West in Texas in the USA[6].

In addition to deficiencies in knowledge management, the fertilizer industry, especially in France, considered that the "worst case scenario" for "in-specification" AN storage were fires with toxic fumes, because they were more likely than massive explosions. In addition, the "envelope approach" of safety case studies led to the view that there were other scenarios (toxic cloud releases of chlorine, ammonia, phosgene) on the plant and in the neighbouring plants which were more severe than an AN explosion.

Once approved in 1989, the land use planning (LUP) enabled local authorities to freeze the urban development, but there were buildings and houses already close by and no retroactive force to expropriate these properties. In addition, the safety perimeters were under-estimated because scenarios were incidents rather than worst cases. This occurred as an outcome of negotiation between the regulator and operator after Seveso I regulation to find a way to value the financial investment of plants in prevention measures and value them in terms of a reduction of effects distances on the LUP map.

Some root causes will remain unknown. Indeed, human and organisational factors investigations and organisational analysis were not the standard at that time (see investigation developments after Columbia space shuttle loss in 2003 and Texas City refinery 2005 explosion). However, investigations found weaknesses in the integration of the workers, subcontractors, stakeholders in the risk assessment, management and governance as well as in subcontractor management especially in competencies in safety and chemical properties of AN.

Some changes in the aftermath of the disaster

Since then, the new French law no2003-699 of 30 July 2003 on technological risk prevention was implemented to address the first lessons from AZF accident[1, 7, 8]:

- A need for better governance of land-use planning around existing and future plants. State, mayors and operators will be in charge to cooperate, prepare, negotiate and define land-use planning restrictions based on Technological Risk Prevention Plans (PPRT). Land use planning restrictions rely on the safety perimeters established on effects distances of several scenarios that are extracted from the safety case report. At the end of 2016, the ministry in charge mentions 394 PPRT defined with 90% approved, on 825 cities urban area, that lead to the exclusion of inhabitants or purchase of 1000 houses.
- A need for a fair compensation of the costs of protection measures to enhance robustness to known scenarios. Constructive measures issued from the PPRT to reduce the vulnerability of the stakes (e.g. blast proof windows) are declared by citizens living within the PPRT perimeter to benefit from a tax deduction. The cost would be shared by the four stakeholders — the inhabitants, the town, the company and state. Approximately 20-30000 houses or flats have been requested to protect their homes in France.
- A need to improve the insurance mechanism to foster the recovery of the territories around the Seveso II plants. An insurance mechanism is activated to help citizens by reducing the time of compensation after a major technological accident as performed for natural disaster.
- A need to improve risk governance around Seveso II plants. Local committees for information and dialogue (CLIC) are implemented to facilitate the dialogue and information sharing between citizen, operators, local State representative, employee and labor representative and mayors, to contribute to the PPRT and to discuss and share information on incidents, accidents and emergency plans.
- A need to extend the emergency plan to the worst scenario potential impact zone.
- A need for more balanced risk mitigation strategies. Risk assessment has moved from a semi-deterministic approach (with reference scenarios as reasonable worst cases including some probabilistic considerations) to a semi probabilistic approach (where some ranges of likelihood are estimated rather than a number). Approximately 2000 new safety case reports were produced under the new regulation and 200-300 millions of euros were invested by industrial organisations to reduce risk at source.
- A need for more regulation enforcement with an increased number of inspectors' staff from 700 in 2001 to 1400 in mid-2000s.

Learning the lessons despite the remaining uncertainty on direct causes

From a rigorous scientific point of view, it may not seem particularly satisfying to learn lessons while uncertainties remain on the causal chain, especially on the direct causes, as this could lead one to act on some influence factors and levers in safety management and governance that are not relevant for the purpose or result in inaction on issues more relevant for accident prevention.

For the alternative scenarios put forward by various experts with more or less evidence (terrorist attacks, underground electrical arc...), that were not investigated or rejected by the justice litigation, it is true that there were no specific learning loops aimed at correcting these direct causes — so no measures for their risk prevention were implemented. This is probably the main safety issue raised by the trials that receive little or no action to date or that are publicly known.

For the chemical incompatibility scenario, this disaster potentially recalled the risk of manufacturing such materials

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on the same plant. The risk perception, knowledge and safety awareness of workers in those high-risk industries is a requisite and the reliance on the compliance to procedures is not enough[9].

For other root causes of the AZF accident, the lack of certainty on the direct causes and chemical scenario assumed by the justice litigation should not lead to changes being postponed and is not jeopardising the lessons learned that led to changes in France and Europe. First, the off-specification ammonium nitrate risks were found to be underestimated, poorly managed and not regulated. If the chemical scenario was finally judged irrelevant, another accident or event could sooner or later reveal those fundamental vulnerabilities. The complex behaviour of off-specification AN polluted by several compounds and degraded in real conditions did not receive enough attention in safety studies, daily risk management and research.

Similarly, for instance, the land-use planning vulnerabilities that are the result of the historical competition between plant territories and urban areas during the 20th century have been illustrated by Toulouse accident but are not specific to it. They are widespread and were known before the accident. Enschede accident in 2000 in the Netherlands already provided such lessons[10]. Changes to reduce the vulnerability of urban areas of cities can only been managed in the long term over several decades. Therefore, such root causes should be considered as historical vulnerabilities of risk management and governance and the Toulouse accident only highlighted these vulnerabilities. The Toulouse accident generated a shock and provided the "window of opportunity" to trigger some organisational and regulation changes against political and economic constraints. Indeed, that is why we consider accidents as being catalysts for changes. However, some other root causes in risk management and regulation were likely missed due to the lack of depth of investigations on human, organisational and societal factors, which was a common investigation limit at that time.

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