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The damage of the Toulouse disaster, 21 September 2001

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Introduction

A terrible explosion of ammonium nitrate (AN) occurred on 21 September 2001, in Toulouse, in an AZF plant belonging to Grande Paroisse Company, TotalFinaElf Group. The chemicals in the plant were mainly ammonium nitrate, ammonium nitrate-based fertilisers and other chemicals including chlorinated compounds. The explosion took place in a storage warehouse where roughly 400 tons of rejected off-spec material was stored. The TNT equivalent mass of the explosion was estimated by INERIS (l'Institut National de l'Environnement Industriel et des Risques) in the range of 20 to 40 tons of TNT. Thirty people were killed and up to 2242 people injured. The plant was located in the suburbs of Toulouse and the extent of damage was very large both on and off site with a cost estimated by insurers of 1.5 billion euro.

This paper provides information on the damage caused by this incident, with particular emphasis on estimates of the explosion strength, on damages and human effects data, and on a few facts and lessons regarding the response to the effects and land use planning.

Accident description and causes

Brief description of the AN storage warehouse

The explosion took place in a warehouse located between process parts, storage and packaging areas for AN. It was used as a temporary storage of 'off-specification' AN ('downgraded' AN), which was allotted for recycling in the AN-based binary/ternary fertiliser process. These materials came from different process units of the site (fertiliser and technical grade) and did not fulfil requirements (under-sized, downgraded, start-ups and shutdowns, return from customers, production tests as new additives) but had badly defined properties. Also, dirty products may have been present from the cleaning of these units[1].

The warehouse had no gas supply, no steam pipes and only natural light, and was supervised by the dispatch department. Three different subcontracting companies were responsible for handling the downgraded AN to the storage, but no one was in the storage warehouse at the time of the explosion.

The investigation by INERIS[2,3] led to an early estimate of about 300 to 400 tons and to a final estimate of 390 to 450 tons of 'off-specification' AN stored the day before the explosion and enabled the entries during the morning of 21 September 2001 to be retraced. One of the key issues was the nature of the product put on top of the AN storage minutes and hours before the explosion at 10:17 a.m.

The controversy on direct causes

Investigators (company, justice) have not yet agreed on the accident's origins. The controversial key element is identifying the ignition source of the stored AN. Investigations have shown that its origin was neither a fire nor a first explosion followed by the mass explosion. Studies have therefore focused on reviewing the role of contamination in AN decomposition, and in particular on chemical incompatibility. The Justice's main assumption focussed on a reaction between AN and DCCNa (SDIC, sodium dichloroisocyanurate) or AN and ATCC (trichloroisocyanurate acid) that is strongly incompatible and releases trichloramine NCl_3, which is very sensitive and is able to explode. The TotalFinaElf company has focussed mainly on a huge underground electric arc between a transformer on SNPE's site (owned by the French State) and EDF's electric line. Other assumptions, such as a terrorist act or malicious intent have also been investigated, but have not appeared relevant so far.

The explosion

Some information will be given on INERIS's estimates of the overpressure of the explosion and the TNT equivalent mass, and that will be compared with several TNT equivalence masses estimated by various inquiries. Also, some estimates on the AN explosion efficiency and changes in French and EU regulations will be mentioned.

The explosion produced a crater of about 65 x 54 m in diameter and 7 m in depth (see Figure 1)[4,5].

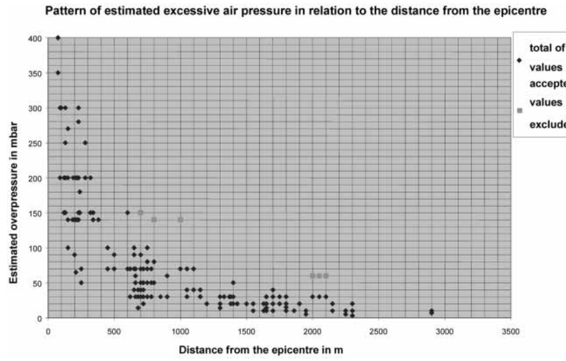

FIGURE 2 : DECREASE IN THE ESTIMATED OVERPRESSURES IN RELATION WITH THE DISTANCE FROM THE CENTRE OF THE CRATER

INERIS overpressure estimates

The IGE's (Inspection Générale de l'Environment) asked INERIS to give its technical assistance during the administration enquiry set up after the explosion in order to report one month later to the French Prime Minister. One of INERIS's tasks was to estimate the strength of the explosion. In this context and among other studies, INERIS carried out a survey of the damage observed ten to fifteen days after the explosion, not only on the site where the explosion occurred but also in the surrounding area within a radius of about 3 km. This survey helped to provide a snapshot of the damage whilst at the same time giving a relatively complete picture (152 damage points were made).

INERIS's overpressure estimates were made on 114 damage points (windows, roofs, walls, buildings) and related to typical overpressure levels or ranges that are provided in the literature[4,5]. The estimated overpressure records are plotted versus the distance from the epicentre of the explosion on Figure 2 (1 mbar = 0.1 kPa).

FIGURE 1 : THE CRATER OF THE EXPLOSION

As one would expect, the estimates shown in Figure 2 show a decrease in overpressure the greater the distance measured from the epicentre. The dispersion of points around a mean curve is comparable to what has already been observed in the course of the same type of work[4,5]. Some measurements were out of line with the general trend, although at the time of the investigation (that had to be reported a few days later), INERIS was unable to interpret these discrepancies. It should be noted that these measurements led to estimates of TNT equivalent greater than the amount of products stored, which does not make sense. Therefore these points were not taken into consideration when working out the weight of TNT that would have been needed to produce an explosion capable of causing the damage observed.

INERIS produced (see Figures 3 and 4) different maps showing the overpressures in and around the AZF site, namely:

- in Figure 3, a representation of the overpressures estimated on the top side;
- and in Figure 4, a representation of the overpressures estimated on the low side.

FIGURE 3 : A REPRESENTATION OF THE OVERPRESSURES ESTIMATED ON THE TOP SIDE

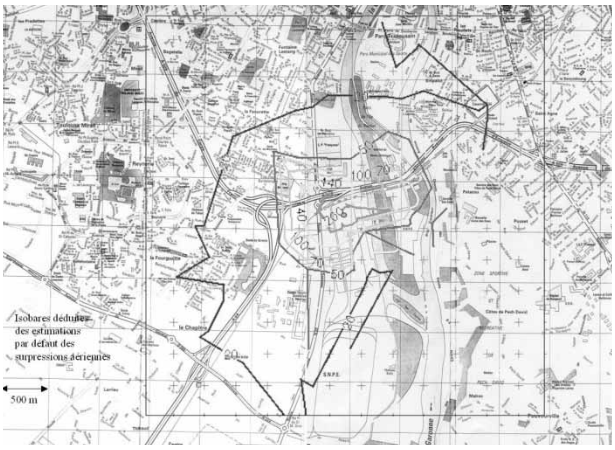

FIGURE 4 : A REPRESENTATION OF THE OVERPRESSURES ESTIMATED ON THE LOW SIDE

TNT equivalent estimate of INERIS

From the analysis of the damage points, it was deduced that the TNT equivalent required to produce the damage observed was between 20 tons and 40 tons. This assessment corresponds to the arithmetic mean of the weight values calculated from the overpressures estimated respectively on the low side and on the top side. Furthermore, it should be pointed out that 54% of the estimates are below 20 tons, whereas 24% of the estimates exceed 40 tons. These statistical data show the disparity in the estimates obtained for the TNT equivalent. This disparity can be explained essentially by the difficulties in interpreting the damage observed within a very short time[4,5].

These estimates were compared to the epicentre damage point where empirical relationships relate the radius of the crater to the amount of explosive involved and to the nature of the ground. The findings seem to be consistent but should not allow us to conclude on these estimates[4,5]. No further interpretation on some projectiles that could have been useful for estimating TNT equivalencies were made. Also, the explosion produced a seismic wave that was estimated at 3.4 on the Richter scale[6], but no analysis had been initiated by the INERIS into this aspect for its investigation.

A comparison with other TNT equivalent mass estimates

The TotalFinaElf investigation commission[7] reminds us that methodologies used for TNT-equivalent estimates are generally not so accurate and result in estimates with a range of uncertainty of one order of magnitude. Therefore, their report listed several estimates of TNT equivalent:

- 165 tons with a range of 140 to 200 tons from SNPE Environment—estimates were mostly based on window damage points;
- 10 to 100 tons from the Laboratoire de Géophysique with several methodologies and with a maximum of 200 tons for some of the methodologies used;
- 15 to 25 tons from Technip by analysing effects on building structures;
- 30 to 40 tons at first and concluded a range of 15 to 40 tons from the TNO by analysing effects on building structures;
- and 20 to 40 tons for INERIS's on windows, building structures, roofs, walls, etc.

The TotalFinaElf internal investigation commission agreed with the estimate of 15 to 40 tons of TNT equivalent because the methodologies used by Technip and TNO seemed more accurate and it confirmed orders of magnitude found by INERIS. A few months later, the Justice mentioned an estimate of 70 to 126 tons for the TNT equivalent mass.

Off-specification AN mass stored and efficiency of the explosion

Then, making a few assumptions about the efficiency of the AN and other AN explosions, it was also possible to estimate the amount of material that exploded on 21 September. Considering the facts that the conditions for the explosion of TNT and for AN in this particular case may be different (detonation in the case of TNT, detonation or explosion in the case of AN) and the composition of off-specification AN stored is fairly heterogeneous so that a partial reaction of the mass which nevertheless exploded remains plausible, it seemed relevant to assume an efficiency coefficient to take into account the differences between the respective capacities of the materials to release energy to create pressure waves.

As shown in Table 1, a range of values for the efficiency coefficient is commonly used. After deducing the range of off-specification AN material weight involved in the explosion, that is to say was transformed as a reactive front went through it, it is possible to deduce the proportion of AN storage that took part in the explosion[4,5]. The other part of AN that had not reacted may have been blasted through the air or left in place.

This assessment of the proportion (5 to 31%) needs to be considered with care bearing in mind the substantial assumptions made and the uncertainties raised[4,5] and will possibly need to be reviewed. On analysis of accidents that have occurred in the past, and particularly to the accident of Oppau in Germany in 1921, it appears that the proportion of the total weight contained in storage that in theory actually takes part in the explosion, is in the range of 10%.

TABLE 1: TNT EQUIVALENCE AND AN

TNT equivalent (tons)	Efficiency coefficient	Tons of off-spec AN involved as reactant	Estimated mass stored	Proportion of mass of AN involved in the reaction/storage
20–40	0.3 (AN in accordance to NFU 42,001) to 1 (AN mixed with 6% fuel)	20–120	390–450	5 to 31%

For information, the TotalFinaElf internal investigation commission considered that the TNT equivalent of AN is 0.3 and that allowed them to estimate that a maximum of 120 tons of AN would have detonated. They also estimated the amount of AN stored in the warehouse was in the range of 370 to 405 tons (76% fertiliser and 24% technical grade) plus 11.5 tons in the transient box at the edge of the warehouse. The Justice, after proposing an estimate of 70 to 126 tons of TNT equivalent, estimated that the AN mass that reacted was about 93 to 168 tons, compared with a 300 to 350 tons of AN stored in the warehouse according to their findings.

New laws for AN in EU and France

With regard to INERIS's recommendations[8], the French Environment Ministry issued a new regulation on 21 January 2002 making it compulsory to use the value of 10% of the AN mass stored into the detonation scenario calculation for safety studies and Land Use Planning (LUP).

AN-based products were classified in Europe, according to the Seveso II Directive (96/82/EC), into two different categories depending on the explosion hazards presented (fertiliser and technical grades). The updating of the Seveso II Directive was adopted in order to integrate two new categories—'off-specification' materials (unclassified AN), taking into account one of the lessons of Toulouse's explosion and AN based composite fertiliser because of other accidents in EU with self-sustaining decomposition.

The damage

An overview of the damage on the site and in the city, its costs and its economical consequences is presented below. Some information on domino effects is also given.

Some figures

The plant was located in the suburbs of Toulouse (750,000 inhabitants) and the extent of the damage was very large both on and off site with a cost estimated by insurers of 1500 million euros.

According to the official statement, 1002 families were re-housed to relatives' homes and a further 125 families were re-housed in mobile homes. According to the local state authority, 27,000 houses were damaged and it took several months to get windows and roofs repaired.

According to the official statement, 17 schools, 26 high schools and several universities were damaged. Some of them needed to be built again including two schools, one high school and one chemical engineering university. The cost of building the new university amounted to 58.4 million euros. According to the local newspaper[9], 74 out of 184 schools were damaged. The cost of repairing these was about 20 million euros. Also, swimming pools, sports halls and a rugby stadium were damaged with repair costs estimated at 9.3 million euros.

Concerning effects on the local economy, 1300 companies were damaged and 172 were severely damaged. Six months later, 29 companies employing 2979 people remained in economic danger. The Government provided more than ten millions euros in assistance.

The public transportation company of Toulouse had 100 buses damaged that were parked between 300 to 500 m from the epicentre, with the total loss amounting to 26 million euros. Among 350 employees on site at the time of the accident, 322 were injured.

The six companies of the chemical zone ceased production for over six months (1100 direct employees and a total of 2500 workers on site) to review their safety studies in order to get another authorisation to operate. In April 2002, roughly six months after the accident, the TotalFinaElf group decided to close the plant (450 direct employees). Later on, the Prime Minister decided to close the phosgene activities of the neighbouring companies (SNPE and Tolochime), resulting in the loss of 492 direct jobs. Their loss was of 450 million euros and 70% of their turnover was suppressed. Approximately 600 subcontractor jobs were also lost.

Domino effect

'The explosion could have had larger human consequences if a storage of toxic gases had been damaged or if a chlorine or ammonia wagon was closer to the location of the explosion'[10]. The effects distances calculated by INERIS after the accident on ammonia scenarios, chlorine scenarios, phosgene scenarios, gave approximately 2 to 3 km for 1% lethal effects and 3 to 10 km for irreversible effects[3]. 'The effects would have been larger because the explosion damaged windows in a large perimeter'. Damage investigation on site by INERIS[4,5] led to an estimate of 50% of the windows broken within the 1600 m of the local emergency plan perimeter (PPI) that hosted 16,000 people[11].

The explosion did not propagate to other AN (technical, fertiliser grades) stored in bulk or bags inside the buildings. AN solution storage was damaged but did not create significant leakage (a temporary pollution of the river Garonne was noted). Little leakage of nitric acid was noted. The ammonia pressurised horizontal tank, at 300 m from the explosion, was protected by a building that was heavily damaged. An ammonia vertical cylinder vessel was distorted a few centimetres without any cover crack[4]. No damage occurred to:

- the liquefied ammonia vertical cylinder vessel at 600 m;
- the chlorine wagon storage inside a shelter at more than 500 m (the shelter was damaged);
- four chlorine wagons and 20 ammonia wagons on standby at 400 m from the explosion because of the building's protection.

Note also that the roof of a vertical cylinder tank of methanol was cracked by the pressure wave[4] at ≅600 m from the epicentre and did not lead to any explosion.

'On the SNPE neighbouring site, no production or storage facilities (phosgene storage was underground) were damaged. Safety barriers functioned (even on the phosgene pipe over the Garonne)'[10]. 'If there was no domino effect here, it's not by chance, but because of the know-how of the pyro-technicians. Their three principles are: (quantities) division, separation, and many safety barriers'. Also the local administration's demand for keeping the toxic gases in the piping and process system was a performance factor. The domino effects were not observed on the phosgene storage because of the distance from the origin of the explosion (more than 600 m which would have given an overpressure of ≅100 mbar or less according to our estimates).

The human effects

Some figures

According to the official statement, 30 fatalities (21 on site—10 direct employees of the company and 11 subcontractors; 9 off-site) and up to 2242 people injured were identified. Among the fatalities off-site, two of them were at neighbouring companies (EDF at 450 m and SNPE at 65 m), one was a student in a high school at 550 m, two were inhabitants of the area, and three were in close stores.

According to the local newspaper[9], up to 9000 people were wounded. Among these casualties, according to the official statement, several figures were recorded: 782 people were hospitalised, 522 persons were treated for hearing problems, 418 suffered several wounds and more than 5000 were treated for shock.

This accident was classified at the highest level of gravity on the EU major accident gravity scale, the 6th level, for several reasons such as number of people injured, number of people hospitalised, the costs… The main reason for the extent of the gravity was the vicinity of the city and its suburbs with 750,000 inhabitants.

The blast effects

Concerning the effects caused by the overpressure wave, three categories were identified: body wounds, eye injuries and ear traumatism (see Table 2).

Concerning eye wounds, 39 severe cases (requiring surgery) were reported and hundreds of non-severe cases were not registered. Concerning ear wounds, by extrapolating data to the city of Toulouse, the Institut de Veille Sanitaire (InVS) estimated 2176 people were wounded[12]. Among 6000 pupils that were monitored within a 2 km radius from the epicentre, loss of ear capacity (>25 dB) was observed in approximately 6% of them. Long-term monitoring is required.

TABLE 2: CATEGORIES OF WOUNDS[12]

	Body	Eye	Ear
226 hospitalised people on 21 and 22 September	93%	10%	2%
588 people that left the hospital during the two days	88%	—	—
Sample of 1673 medical certificates (among 4900 cases) notified at work showed 2910 wounds	68%	1.4%	18%

The long-term health effects

In the days following the explosion InVS, with the Health administration, set up an epidemiological monitoring system of the health impact of the explosion due to environmental exposure. The aim was to monitor people exposed to the explosion effects and to assess these mid- and long-term health effects in order to make recommendations. To assess these effects, the investigation identified three working objectives. At first, the InVS investigation[12,13] focused on identifying the polluting agent releases due to the explosion or later on by the damaged site. Secondly, the available data on the environmental pollutant measured in the Toulouse area were analysed. In parallel, enquiries on more than 50,000 exposed people (workers from Toulouse, rescue services, students, inhabitants of the area) were launched to identify specific disease.

The results of InVS investigations are discussed through two main ways of exposure—by air and by mouth. Concerning the pollutants for which measurements were available for the explosion (NO_2, NH_3, particles), transient (5 weeks or less) eye effects (conjunctivitis but no severe irritations) and respiratory effects were observed for the people living nearby and did not require further monitoring. Concerning the pollutants for which measurements were not available for the explosion (Cl_2, N_2O, HNO_3), it was not possible to quantify exposure. However, no major health effect was observed. For asbestos, no major effects were observed or were expected from the demolition of the factory. Concerning the oral exposure, no health effects were expected from direct (acute or chronic) eating of soil projections with pollutant (As, Cr, Cu, Pb). Also, no health effects were expected from indirect exposure (water, crops). The radioactive sources on site were found and no release was stated.

Among the long-term effects, psychological problems were analysed. According to the official statement, 729 people were treated for psychiatric problems and 497 for shock. A total of more than 5000 people consulted doctors for acute stress and 3556 people were treated by medicines.

The response to the effects

Emergency response and planning

In the days following 21 September, 1570 firemen and soldiers and 950 policemen were involved in the emergency response and housing monitoring. Twelve hours after the explosion, there were 300 vehicles and 900 firemen. The problem was that they arrived without any plan, having had little prior discussion due to phone lines being partly destroyed and the mobile phone network being saturated. The state emergency plan was, however, efficient[14].

The internal and external emergency plans were not prepared for this scenario and its gravity. Previous training helped the firemen and others to respond well, but the first firemen on the scene did not have adequate protective equipment against toxic clouds and had no devices to detect toxic gases.

Informing the public was a problem without the radio. The communication network should be designed to have a separate network for crisis management[14].

Compensating the victims and repairing damages

According to the Fédération Française des Sociétés d'Assurance, 75,000 claims of damage (7000 were from business activities) were notified to insurers, 10% of whom were companies accounting for 90% of the compensation payments. Approximately 30,000 houses and 5000 vehicles were damaged. One year later, the insurers had compensated 50,000 cases.

In some cases TotalFinaElf accepted and compensated for damages before the trial. As a result of the Toulouse disaster, new law in France for technological risk requires victims to be compensated faster in the case of a major accident, by making it compulsory for the victim's insurer to pay for the damages. Then the victim's insurer will deal for compensation with the industrial insurer. This improvement was also recommended by the European Parliament after the event[15–17] as they considered the compensation process too slow despite the efforts made by insurers and the company.

Some facts on Land Use Planning (LUP)

Finally, a few points to address the LUP factors that contributed to the disaster and also on LUP decisions taken after the disaster.

Estimated effects zones

The damage investigation may help to mark out the different zones where the critical overpressure thresholds of 140 and 50 mbar were reached or exceeded. As a matter of interest, these thresholds are used in hazard studies for ICPE* in order to mark out the zones where the lethal effect (threshold of 140 mbar) and irreversible effects (threshold of 50 mbar) on human health can be experienced. Thus, the range of 20 to 40 tons adopted for the TNT equivalent implies:

- a distance roughly between 280 and 350 m for the critical overpressure of 140 mbar;
- and a distance roughly between 680 and 860 m for the critical overpressure of 50 mbar.

Historical land use planning and after the accident

From 1914 to 2000, Toulouse's city population multiplied by five and the urban area multiplied by ten (750,000 inhabitants in the urban area in 2000). In the seventeenth century an explosives factory was built close to Toulouse and in 1840, it had a non aedificandi zone. But three accidental explosions later and probably due to urban pressure, it was removed from the inner city twice. In 1928, another aedificandi zone was proposed but could not struggle with the urban development. In 1947, another LUP was approved but not applied because of the development requirements. The urgency was to build flats, universities, roads[10,11] (see Figure 5).

In the 1980s, following the Seveso shock, there was a growing consciousness of risk. So, in 1983, safety studies commenced and LUP was approved in 1989. After the Seveso II Directive in 1996, the local plan finally took a clear position for long-term change[11].

Concerning the LUP of 1989 for the three sites (AZF, SNPE, Tolochimie), it was based on toxic gas release scenarios (chlorine, ammonia and phosgene).

The major accident scenarios for the LUP in 1989 for the AZF site were: a pipe break when unloading a wagon with a release of 350 kg of chlorine, lethal effects (LE) 50%, were calculated with confinement at 465 m and at 875 m for the irreversible effects on health (IE, based on IDLH); and a 14,900 kg ammonia pipe break (LE at 894 m and IE at 1600 m).

The major accident scenario at SNPE was a leak of 550 kg of phosgene after a pipe break (LE 50% at 600 m and IE at 1175 m with confinement) and at Tolochimie a leak of 1100 kg of phosgene after a pipe break (LE 50% at 900 m and IE at 2150 m).

The LUP-PIG perimeter, (based on LE) for the three sites included 1130 people. The external emergency plan

FIGURE 5: AFTER THE EXPLOSION, THE AZF SITE INSIDE THE RECENT SUBURBS OF THE CITY OF TOULOUSE

perimeter (based on IE) included approximately 16,000 people[11]. INERIS[3] calculated in 2001 the effects distances that were wider for selected (representing the hazard potential) scenarios on toxic gas releases.

The AN explosion scenario was not considered because of the low probability of AN explosion in normal operations (for a product respecting the norm and being not polluted, the 1990 safety study reviewed in 1995, did not consider any explosion for a 15,000 tons of AN 33.5% because of the requirement for a powerful detonator). A fire scenario on AN was considered among 36 accident scenarios in the safety study (this was the choice of the UNIFA, the group of fertiliser manufacturer in France). The AN off-specification storage was not covered by the Seveso II Directive and was not identified in the safety studies.

'The damage went far beyond these 1989 LUP-PIG and LUP-emergency response distances'[11]. But on the other hand, greater distances would not have lowered the impact because the urban areas were built before 1989 and the LUP had no retroactive force for existing sites[11]. Without the domino effect, the majority of the off-site fatalities were inside this first LUP-PIG zone based on lethal effects. Also, as mentioned by INERIS[3], the estimated distance (of 280 to 350 m) for lethal effects (140 mbar) was inside the LUP-PIG zone. These authors[11] also stated that since that procedure was launched in 1989, the state services applied it well without authorising any new housing. The final lessons of this historical analysis are that it is possible to act inside the LUP zone, which appears too small today and that it is not possible to interfere on a housing built before the LUP creation[11].

As mentioned earlier, the TotalFinaElf group closed the AZF site. This disaster has noticeably activated the risk (damage potential) consciousness for the neighbouring chemical sites and this led to the closing of the phosgene activities.

* *ICPE that stands for Installations Classées pour la Protection de l'Environnement (Classified Installations for the Protection of Environment); total of ≅50 000 sites in France including Seveso II sites that have to assess accidental scenarios in safety studies,*

LUP in the new law

In the new law, the French Environment Ministry identified two main issues:

- How to deal with the existing situation without increasing the hazard?
- How to treat very hazardous cases?

The first principle is that each increase of a LUP perimeter from industrials will lead to compensation from them. In the vicinity of Seveso sites, PPRT (technological risk prevention plan) will define no (or reduced) man's land and those that need housing protections (windows, …). This plan could use financial incentive tools in order to let the people leave their house or in order to expropriate them. They will be managed by local stakeholders including the public. The cost will be shared by companies, local authorities and the State. The government considers this proposal as new in Europe, where implementation will take years.

Also the role of insurers was highlighted in promoting risk management and risk reduction. The new safety studies will have to estimate probabilities of occurrences of major accident scenarios with the cost of the potential economical damage to the goods (the new law focuses only on 670 Seveso site high threshold versus a total of 1250 Seveso Sites in 2001). Thus, the industrials will be interested in being risk secured with an insurance contract.

In addition, a financial damage assessment based on accident scenarios will be required in the annual financial report of the company.

Conclusion

As mentioned previously, the aim of this paper was to provide information and references that could constitute factual data or lessons that could be applied elsewhere.

The figures show the effects of this major accident that resulted in a disaster due to the vicinity of the Toulouse suburbs.

Some of the lessons[15] of this experience have led to regulatory changes in France and in the EU. Firstly, despite the uncertainty of its cause, the explosion of off-specification AN serves as a severe reminder of the inherent hazards of AN that were thought to be well known. Off-specification AN is now covered by the EU Seveso II Directive and the TNT equivalent estimates of the explosion have helped the regulators to define the AN storage threshold that the regulation should cover.

After this and other disasters (such as Enschede in 2000), one of the conclusions reached is that controlling major accident hazards by reducing the risk on-site is not sufficient to promote sustainable development for both industry and urban areas without LUP in the next few decades[18]. Therefore, the LUP in the Seveso II Directive modification (16 December 2003) is clearly required as a tool to prevent the exposure of people and environment. The new law in France (July 2003)[19] already requires such a tool and will experiment with the means of achieving sustainable development in a long-term perspective.

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