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Ádám Berger[1]

Evaluation of the Experience of International Accidents Related to the Storage and Handling of Ammonium Nitrate Fertilisers

Due to its high nitrogen content, ammonium nitrate is a popular fertiliser raw material worldwide and is also used as an ingredient in explosives in mines due to its explosiveness. As a result, several dangerous plants in the world are involved in the storage and handling of ammonium nitrate. In order to prevent a serious incident involving the substance, a number of national and international regulations exist. However, despite these strict laws and official controls, serious accidents have occurred that have resulted in significant material, environmental, and last but not least, human losses. The aim of the publication is to describe the major international accidents that have occurred during the storage and handling of ammonium nitrate. Furthermore, a summary is presented of the causes and main experiences identified during the investigation of these injury events.

Keywords: **ammonium nitrate, storage, explosiveness, damage event**

1. Introduction

Over the last hundred years or so, there have been a number of incidents involving ammonium nitrate preparations, including those related to ammonium nitrate fertilisers. The substance is treated accordingly by legislators at both international and national level. The incidents that have occurred share one main common parameter, namely the substance. Linked to this parameter are various risk factors, such as human error, technical failure, external environmental factors, and often some combination of these. With the present publication, the author aims to identify and systematise the damage events related to ammonium nitrate fertilisers that have occurred in the last one hundred years, and to evaluate the consequences and, as a preventive measure, to summarise the experience gained. As far as possible, reports describing these

[1] University of Public Service, Faculty of Water Sciences, Department of Water and Environmental Security, e-mail: berger.adam@uni-nke.hu

incidents and professional written communications were searched. The methodology used included the criterion that the consequences described should be supported by at least two consistent source works, where possible.

2. Properties and categorisation of ammonium nitrate

The advantage of ammonium nitrate is that it contains equal proportions of nitrogen (in the form of ammonium and nitrate ions). It is therefore one of the most widely used fertilisers worldwide. Another advantageous but dangerous property is its explosive nature, which makes it an important industrial raw material (e.g. explosives, rocket propellants). Ammonium nitrate is not combustible by itself, but as a strong oxidising agent it promotes combustion even in the absence of air, increasing the fire risk of other combustible materials. It also poses the risk of explosion in confined spaces, and the nitrogen oxides and ammonia released during combustion can cause severe poisoning. Following the ammonium nitrate explosion in Toulouse, France (2001), the international regulations were tightened [Decision 1348/2008/EC[2] and Regulation (EC) No 2003/2003[3]]. In addition, ammonium nitrate and ammonium nitrate-based fertilisers are classified in a separate category under the Seveso Directive.[4] In our country, *Government Decree 219/2011 (X.20.) on the Protection against Major Accidents Involving Dangerous Substances* (hereinafter: Vhr.) lists fertilisers containing ammonium nitrate as dangerous substances. The threshold values for each category of ammonium nitrate (hereinafter: AN) are set out in Table 1.[5]

Table 1: Thresholds for AN categories
Source: Compiled by the author based on Government Decree 2019/2011

Dangerous substances	**Qualifying quantity (tonnes) for the application of**	
	Lower-tier requirements	**Upper-tier requirements**
Ammonium nitrate – fertilisers capable of self-sustaining decomposition	5000	10 000
Ammonium nitrate – fertiliser grade	1250	5000
Ammonium nitrate – technical grade	350	2500
Ammonium nitrate – 'off-specs' material and fertilisers not fulfilling the detonation test	10	50

2 Decision 1348/2008/EC Amending Council Directive 76/769/EEC as Regards Restrictions on the Marketing and Use of 2-(2-Methoxyethoxy)Ethanol, 2-(2-Butoxyethoxy)Ethanol, Methylenediphenyl Diisocyanate, Cyclohexane and Ammonium Nitrate.
3 Regulation (EC) No 2003/2003 of the European Parliament and of the Council of 13 October 2003 Relating to Fertilisers.
4 Brigitta Bíró: Veszélyes, mégis hasznos, ráadásul hatalmas üzlet, mi az? Interview. *Ludovika.hu,* 06 October 2020.
5 Government Decree 219/2011 (X.20.) on the Protection against Major Accidents Involving Dangerous Substances.

The self-sustaining decomposable category includes AN-based compound fertilisers with N content derived from AN:

- more than 15.75 weight% but not more than 24.5 weight% and/or with a total combustible/organic material content not exceeding 0.4 weight% or which meets the requirements of specific legislation
- 15.75 weight% or less by weight with no limit on the combustible content
- and which are capable of self-sustaining decomposition according to the UN Manual of Tests and Criteria, Part III, Section 38.2

The fertiliser purity category refers to pure AN-based fertilisers and AN-based compound fertilisers with N content derived from AN:

- greater than 15.75 weight% (for AN and ammonium sulphate mixtures)
- more than 24.5 weight% (excluding AN mixtures with dolomite, limestone and/or calcium carbonate of at least 90% purity)
- greater than 28 weight% (for AN mixtures with dolomite, limestone and/or calcium carbonate of at least 90% purity)
- and which meet the requirements laid down in specific legislation

Technical quality is when:

- the N content from AN:
  - more than 24.5 weight% but not more than 28 weight% and with a combustible matter content not exceeding 0.4 weight%
  - 28 weight% or more and with a combustible material content not exceeding 0.2%
- or for aqueous AN solutions in which the concentration of AN is greater than 80 weight%

“Non-conforming” products and fertilisers include those that do not meet the detonation test. The following points shall then be considered relevant:

- materials separated during the manufacturing process for quality reasons, as well as AN and AN preparations, pure AN-based fertilisers and AN-based compound/complex fertilisers referred to in the criteria of the previous two categories, which are returned from the end-user for remanufacture, recycling or treatment for safe use, or returned to a manufacturer for temporary storage or recycling because they no longer meet the quality standards specified in those categories
- for fertilisers referred to in the first point of the category “self-sustaining” and in the category “fertiliser purity”, which no longer comply with the requirements laid down in specific legislation[6]

[6] Ibid.

3. Potential dangers of ammonium nitrate-related activities

The first thing people think of when they hear of AN-related incidents in recent years is the powerful, devastating explosion that is perceived as a threat. However, for the storage, use and transport of AN, the hazards to be assessed in a risk assessment are:

- fire
- degradation
- explosion

Although not flammable by itself, it increases the risk of fire in the presence of other combustible materials. The conditions under which a fire may start are:

- temperatures above 170°C (this is the melting point and above 210°C it will decompose)
- excess contact with air (hygroscopic material)
- contamination with incompatible substances (avoid mixing with: combustible substances, reducing agents, acids, alkalis, sulphur, chlorates, chlorides, chromates, dichromates, nitrites, permanganate, metallic powders, or substances containing copper, nickel, cobalt, zinc or their alloys)
- proximity to a heat source or a fire (above its melting point, various decomposition processes take place, and the presence of bubbles in the molten AN increases the probability of explosion)
- failure to comply with work safety regulations (inadequate safety distance from the loaded AN, e.g. during welding operations)

Explosive decomposition (disintegration) can also occur under rapid heating. Fire melts all types of AN and decomposition occurs with the release of toxic fumes with a characteristic yellowish brown colour. However, some AN fertilisers are capable of self-sustained decomposition on heating. In this case, the degradation can extend to the entire mass of the stored material and can produce large amounts of toxic fumes even after the original heat source has been removed.

Friction and impact during normal handling of the AN will not cause detonation, but will occur after a higher force is applied. The sensitivity of the material to explosion depends, for example, on physical parameters (density, grain size, porosity) and chemical composition. Literature suggests that the critical volume (melt diameter) to cause an explosion is at least 3 m. This suggests that explosion is unlikely for less than 300 t.[7]

In addition to the immediate dangers described above, the risks associated with spraying should also be mentioned. AN is harmless under normal conditions and circumstances, but in high concentrations and as dust it poses a hazard that must be prevented. Inhalation causes coughing, which should be prevented by local aspiration or the use of respiratory protection. Contact with the skin may cause reddening of the affected area, so the use of protective gloves is always recommended. In contact

[7] József Dobor et al.: Az ammónium-nitrát műtrágyák tárolásából származó veszélyek és az ebből fakadó súlyos balesetek megelőzésének lehetőségei. *Hadmérnök,* 8, no. 2 (2013). 182–190.

with the eyes, redness, irritation, pain may occur and well-fitting eye protection should be used. Ingestion causes headache, abdominal discomfort, bluish lips, skin and fingernails and weakness.[8]

They analysed 70 accidents that occurred in the period 1961–1995 and found the following:

- in 15 cases the accident was related to storage
- of these 15 cases, 4 were confirmed to be mixed with combustible material (fire)
- 11 of 15 accidents were related to self-sustained decomposition or decomposition from an external heat source
- 1 out of 15 incidents may also involve the explosion of a small part of the stored material
- other incidents included accidents involving workers, mainly involving burns (incidents involving hot AN solution)[9]

In the period 1995 to the present, 14 AN storage/handling accidents have been recorded, which can be analysed as follows:

- in 10 cases, AN was mixed with combustible material and a fire started
- in 5 cases, the accident was linked to a degradation process
- in 12 cases, the variable proportion of AN exploded

The above analyses show that 3 scenarios are more relevant from the point of view of risk assessment and thus external security:

- toxic gases released during decomposition by an external heat source
- toxic gases released from self-sustaining decomposition
- and the explosion

In the two periods under review, the number of fire and explosion accidents increased significantly in the second period. One of the reasons for this is the increasing intercontinental nature of transport over the years. Much more material is transported in much larger quantities on a given vehicle, which can be a major source of danger in rail and road transport (e.g. Iran, Neisapur, 2004; Mexico, Monclova, 2007). However, cargo accumulated in ports during maritime transport also poses a significant risk (e.g. Tianjin, China, 2015; Beirut, Lebanon, 2020).

One of the most vulnerable sectors for the transport of dangerous goods by road, such as ammonium nitrate fertilisers, is agriculture. For this reason, knowledge of the regulatory systems for the transport of dangerous goods should always be part of the curriculum for the training of agricultural specialists at tertiary level.[10] Another preventive tool in the field of storage and transport could be the provision of fora jointly run by competent authorities, stakeholders and operators. These would provide users with useful information by presenting instructive case studies,

[8] International Chemical Safety Cards (ICSCs): *Ammonium Nitrate.*

[9] Dobor et al. (2013): op. cit.

[10] Csaba Almási et al.: Mezőgazdasági felhasználású veszélyes áruk közúti szállítási tapasztalatai – 1. rész. *Védelem Tudomány,* 5, no. 2 (2020). 118–136.

investigative experiences of accidents that have occurred and clarifying the legal issues that arise.[11]

4. Presentation of major international accidents related to the storage and handling of ammonium nitrate

In this section, due to the limitations of the publication, accidents related to AN, which the author considers to be more significant, are presented. AN-related accidents that resulted in fatalities during the period 1916–2021 are shown in Figure 1 and summarised in Annex 1. Figure 1 shows that the majority of these events occurred in North America, Europe and China. Two or two events occurred in Australia and Oceania and the Middle East.

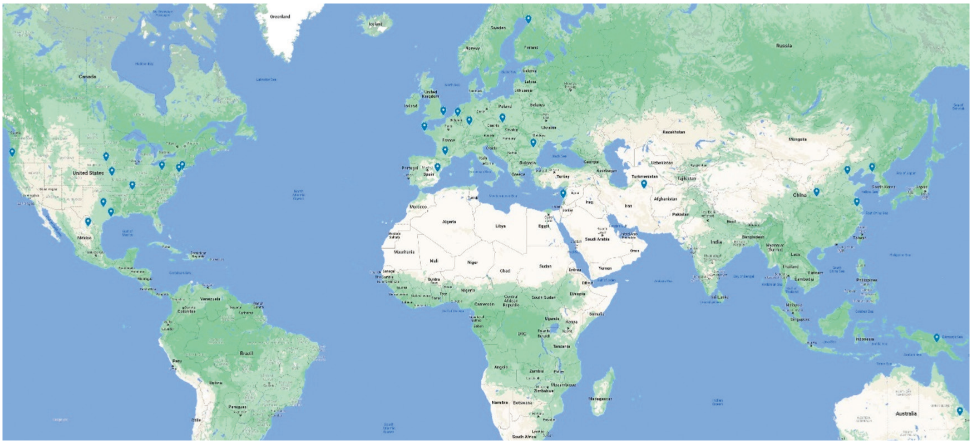

Figure 1: Fatal AN accidents (1916–2021)
Source: Compiled by the author based on Google, INEGI, 2021.

One of the first major industrial disasters of the 21st century occurred on 21 September 2001 at the AZF fertiliser factory in Toulouse, France. There had been no fire prior to the explosion of 300–400 t of granular AN, but several successive explosions were reported, leading the authorities to suspect a terrorist attack. Experts estimated the explosion to have a magnitude of 3.4 on the Richter scale and a yield equivalent to 20–40 t of TNT. The accident killed 30 people and injured 2,442 others. Windows were also broken 5 km from the explosion site, creating a crater 10 m deep and 50 m wide. The aggravating factor is that since the factory was built, the surrounding areas have become built-up and densely populated. This

[11] Csaba Almási et al.: Mezőgazdasági felhasználású veszélyes áruk szállítási tapasztalatai – 2. rész. *Védelem Tudomány,* 6, no. (2021). 73–90.

explains the high number of dead, injured and damage to buildings (estimated at EUR 1.5 billion).[12]

On 18 February 2004, runaway wagons caused a serious accident in the Iranian city of Neisapur, killing 295 people and injuring 460 others. The materials (sulphur, petrol, fertiliser) in the wagons were all highly explosive and flammable. The runaway wagons drifted for several kilometres and collided with buildings in a village, causing a fire and explosion.

On 22 April 2004, 161 people were killed and at least 3,000 injured in an accident at a railway station in Ryongchon, North Korea. The official position is that the incident was due to human error, in which an oil tanker collided with two freight trains loaded with AN. As a result of the explosion, the railway station and most of the buildings within 500 m of it were destroyed. A further 8,000 houses were damaged and two 10-metre deep craters were created.[13]

The explosion in West, Texas, on 17 April 2013 is believed to have been caused by the improper storage of more AN than would otherwise have been permitted. The accident resulted in a crater 23 m wide and 3 m deep, damage to 350 buildings and the destruction of 142 others. The death toll was 15 and the number of injured 260. As in the Toulouse accident in 2001, the fact that the surrounding areas, which were still empty when the factory was built, have been built on over the years (housing, schools, retirement homes, apartments) and have become densely populated, was a factor in the accident. Experts estimated the explosion to be equivalent to 11 t of TNT and to have a magnitude of 2.1 on the Richter scale.[14]

On 12 August 2015, stored nitrocellulose caught fire in the port of Tianjin (China). The fire spread to 800–1,300 t of AN in the surrounding warehouse, which subsequently exploded. The accident killed 173 people and injured 798 others. Buildings, stored goods, surrounding residential blocks and the railway station were destroyed within a 1 km radius of the warehouse. But buildings beyond this radius were also severely damaged. A further aggravating factor was the dispersion of sodium cyanide as a result of the accident, which subsequently caused significant destruction to the living water.[15]

A recent event is the powerful explosion that occurred on 4 August 2020 in the port of Beirut (Lebanon), killing more than 200 people and injuring at least 6,500 others. The U.S. Geological Survey recorded the event as a magnitude 3.3 seismic event. This is confirmed by the devastating impact of the explosion, with over 300,000 people losing their homes, in addition to the death and injury figures, and property damage estimated at US$10–15 billion. The impact of the accident was compounded by the fact that it occurred during the pandemic caused by Covid-19 and the explosion destroyed 50% of the total medical stockpile as it was stored in the port. In addition, the country has been in a serious political

12 Nicolas Dechy – Yvon Mouilleau: *Damages of the Toulouse Disaster, 21st September 2001.*

13 Sean Gillis – Sreenivasan Ranganathan: *Variables Associated with the Classification of Ammonium Nitrate – A Literature Review.* Fire Protection Research Foundation, March 2017.

14 Ronald J. Willey: West Fertilizer Company Fire and Explosion: A Summary of the U.S. Chemical Safety and Hazard Investigation Board Report. *Journal of Loss Prevention in the Process Industries,* 49, Part B (2017). 132–138.

15 Sen Xu et al.: *2015 Tianjin Explosions.*

and economic crisis for several years, which has been exacerbated following the incident.[16]

5. International experience of accidents involving the storage and handling of ammonium nitrate

Two of the accidents described in the third part relate to the densely populated area, two to rail transport and two to maritime transport (docking). However, Annex 1 shows that several similar incidents occurred during transport, storage and handling. Globalisation, the intercontinental nature of transport and the desire of economic operators to increase production volumes (stockpiling) mean that further AN-related accidents (including those involving AN) are likely to occur in the future. Although there have not yet been any fatal or serious injury accidents involving AN in Hungary (24 April 2008, road 403, Nyíregyháza; 10 September 2008, M7 motorway, Pusztazámor), the author's personal experience suggests that efforts should be made to comply with and enforce the current regulations at both national and international level. International experience has shown, for example, that the origin of the AN stored is not clearly identified, that storage in accordance with regulations is not managed (e.g. 4 August 2020, Beirut), that the quantity stored exceeded the permitted level (e.g. 17 April 2013, Beirut, West, Texas), maintenance was not performed according to specifications, or workers were not adequately trained on the stored material (e.g. 21 September 1921, Oppau, 30 August 1972, Taroom, Queensland, 13 December 1994, Port Neal, Iowa). Based on the examples listed above, the following principles should be followed:

- a risk analysis according to the properties and hazard level of the substance to be stored (classification in a category fixed in the Vhr)
- providing workers with the knowledge communicated in the safety data sheet of the material to be stored, and keeping the sheet in an easily accessible place
- appropriate choice of storage site (enclosed/open space, separation from other materials to avoid mixing, adequate infrastructure)
- installation and continuous monitoring of the necessary security system (e.g. smoke detector, camera, automatic extinguishing system)
- storage facilities and buildings should be non-combustible materials and should ensure that additional combustible materials are kept away from the cargo
- maintenance operations should only be carried out by suitably qualified personnel, who should be provided with all necessary information before starting operations

[16] H. Talib Hashim et al.: Beirut Explosion Effects on Covid-19 Situation in Lebanon. *Disaster Medicine and Public Health Preparedness,* 1–2 (2021).

- following any contamination of the AN, professional disposal, separation and prompt disposal in accordance with the regulations[17]

In addition to these key principles, it remains important to thoroughly investigate accidents that have occurred, identify the causes and consequences, document lessons learned and develop good practices for AN storage, handling and transport activities.

6. Conclusion

Due to its high nitrogen content, ammonium nitrate is a popular fertiliser feedstock worldwide. However, in addition to its favourable nutritional values, high risk factors must be taken into account during its production, storage, transport and use. The aim of this publication was to summarise the international accidents that have occurred during the above-mentioned activities and to describe the accidents that are considered to be the most significant in terms of the impact of the incident. The final chapter of the publication summarises the root causes identified during the investigation of the incidents and the main lessons learned. On this basis, the author makes a number of key recommendations which, if followed, could minimise the risk factors induced by the substance under investigation.

Annex 1: Summary table of fatal AN accidents (1916–2021)
Source: Compiled by the author.

S.n.	**Country**	**Location**	**Date**	**Material**	**Quantity (tonnes)**	**Damage suffered**	**Dead**	**Injured**	**Reason/memo/ experience**
1.	United States	Gibb-stown, New Jersey	14 January 1916	AN	3		1	12	The explosion was probably caused by overheating caused by a blocked extractor hood.
2.	United Kingdom	Faversham, Kent	2 April 1916	AN + TNT	150 + 15	A crater 45 m in diameter and 5 me deep. 5 buildings were completely destroyed. Buildings were damaged up to 200 m from the explosion.	108		A fire broke out in the ammunition factory, spreading to a storage area of 15 t of TNT and 150 t of AN.

[17] Dobor et al. (2013): op. cit.; Zsolt Cimer et al.: *Iparbiztonsági szakismeretek. Módszertani kézikönyv a veszélyes anyagokkal kapcsolatos súlyos balesetek elleni védekezéssel foglalkozó gyakorló szakemberek részére.* Budapest, Hungária Veszélyesáru Mérnöki Iroda, 2020.

S.n.	Country	Location	Date	Material	Quantity (tonnes)	Damage suffered	Dead	Injured	Reason/memo/ experience
3.	United States	Oakdale, Pennsylvania	15 September 1916	AN	3	The property damage is approximately USD 3,000. The impact of the explosion was felt up to 11 km away.	6	8	The suspected reason is that the nitric acid used to make AN was contaminated.
4.	United States	Morgan, New Jersey	4 October 1918			Days of explosions and fires. Debris scattered over a 2 km radius.	100		One local historian believes the explosion was caused by human error, but there are also theories that the Germans sabotaged the plant.
5.	Germany	Kriewald (Upper Silesia)	26 July 1921	AN	30	A crater 19 m wide and 6 m deep.	19	23	2 pieces of AN, transported and stored in railway wagons, were crushed and used to detonate mining explosives.
6.	Germany	Oppau	21 September 1921	AN + AS 50–50 mixture	450	USD 7 million in property damage. 80% of Oppau's buildings were destroyed. 6,500 homeless. Windows were also smashed 30 km away. Crater 90–125 m wide and 19 m deep.	561	2,000	The compacted material was extracted from the silo with a pickaxe and a small amount of dynamite. 10% of the 4,500 t of fertiliser exploded.
7.	United States	Nixon, New Jersey	1 March 1924	AN	2	The small industrial town and 40 buildings were destroyed.	20	115	There was a fire and several explosions in the plant, which spread to the AN warehouse. The AN was mixed with nitric acid.

S.n.	Country	Location	Date	Material	Quantity (tonnes)	Damage suffered	Dead	Injured	Reason/memo/ experience
8.	Belgium	Tessend-erlo	29 April 1942	AN	150	The plant was destroyed and 700 buildings damaged in a 50–11 m crater.	189	900	The crushed AN was decapitated, initially with pickaxes and then with explo-sives. During the release, the AN exploded.
9.	United States	Milan, Tennesse	2 March 1944	AN	2,18	Damage within 200 m.	4	17	The air compres-sor may have failed, causing (the otherwise oil-contaminat-ed AN) to catch fire and burst.
10.	United States	Texas City, Texas	16–17 April 1947	AN	2,300 + 960	Windows were broken at a dis-tance of 64 km. 60 million USD in property damage.	581	>2,000	When the ship was being loaded, a fire was detected in the hold, which subsequently exploded. As a result of the explosion, another nearby cargo vessel carrying 960 t of AN also caught fire. It also exploded a few hours later. The approximately 500 t of AN stored in the port also caught fire but did not explode.
11.	France	Brest	28 July 1947	AN + various flam-mable products	3,309	Serious damage in the port of Brest.	29	>250	A fire broke out on the boat, which then exploded.
12.	United States	Roseburg, Oregon	7 August 1959	AN + dy-namite	4.5	Several blocks of the city centre were destroyed. USD 9 million in property damage.	14	125	A truck carrying dynamite and 4.5 t of AN caught fire and exploded.
13.	Finland	Oulu	9 January 1963	AN	10	Buildings in the city were dam-aged.	10	>12	The AN has caught fire.

S.n.	Country	Location	Date	Material	Quantity (tonnes)	Damage suffered	Dead	Injured	Reason/memo/ experience
14.	Austral-ian	Taroom, Queens-land	30 Au-gust 1972	AN	12	More than 800 hectares burned. A crater was also created where the explo-sion occurred.	3	0	The truck caught fire due to an electrical fault. The melted AN mixed with the fuel and then exploded.
15.	United States	Kansas City, Missouri	29 No-vember 1988	ANFO (AN con-taining fuel oil)	25	2 craters, about 2.4 m deep. Win-dows have broken over an area of 26 km.	6		It was deter-mined that the explosion was caused by a fire, which was start-ed by deliberate arson.
16.	Papua New Guinea	Porgera's gold mine	2 August 1994	AN emul-sion	80	The plant was destroyed. A cra-ter 40 m wide and 15 m deep was created.	11	0	A fire broke out in the area around the storage facilities, causing the AN to burst. No ex-act cause was found during the investigations.
17.	United States	Port Neal, Iowa	13 De-cember 1994	83% AN solution	5,700	The plant was destroyed. The release of AN continued for 6 days after the explosion. As a consequence, groundwater be-neath the facility was contaminated by chemicals released as a result of the explosion.	4	18	The accident occurred due to unsafe operation of the plant, including poor maintenance and inadequate training of workers. During the shutdown, the pH of the neutralisation vessel contents dropped to unusually low levels and leaks from other equipment led to the introduc-tion of chloride ions that cata-lysed the final reaction.

S.n.	Country	Location	Date	Material	Quantity (tonnes)	Damage suffered	Dead	Injured	Reason/memo/ experience
17.									Unaware that the 18,000-gallon capacity neutralisation vessel was in a highly acidic and contaminated state, Terra staff injected superheated steam to try to prevent the contents of the vessel from freezing due to the winter cold. The energy of the superheated steam injected led to a chemical reaction of the sensitised AN solution and subsequent explosions.
18.	China	Xingping, Shaanxi	6 January 1998	Liquid AN	27.6	The plant was destroyed. The material damage is estimated at between USD 9 and 11 million.	22	58	The explosion origin of the accident was the Phase II ammonium nitrate solution tank, and the solution tank itself was contaminated with oil and chloride ions, which made it extremely unstable.

S.n.	Country	Location	Date	Material	Quantity (tonnes)	Damage suffered	Dead	Injured	Reason/memo/ experience
18.									The cause of the accident may be that the ammonium nitrate solution was contaminated with oil and chloride ions, which enhanced the explosion sensitivity of the ammonium nitrate solution and reduced the critical temperature of self-heating, causing combustion and explosion.
19.	France	Toulouse	21 September 2001	Eyelashes AN	300–400	5 km away the windows were broken. A crater 10 m deep and 50 m wide was created. Material damage is estimated at €1.5 billion.	30	2,442	There was no fire before the explosion, which was probably caused by an accident. At the time of construction, the surrounding land was vacant, and over the years it has been built up and inhabited.
20.	Iran	Neisapur	18 February 2004	Sulphur, AN, petrol, cotton wool	51 railway wagons	The runaway train cars crashed into the village buildings and exploded.	295	460	The wagons derailed and then drifted into a village. The materials in the wagons were all highly explosive (sulphur, petrol, fertiliser) and flammable.
21.	Spain	Barracas	9 March 2004	AN	25	A crater 30 m in diameter and 5 m deep. It has torn down more than 100 m of protective barriers.	2	5	Following a road accident, the truck overturned, caught fire and then exploded.

S.n.	Country	Location	Date	Material	Quantity (tonnes)	Damage suffered	Dead	Injured	Reason/memo/ experience
22.	North Korea	Ryong-chŏn	22 April 2004	AN		The railway station and most buildings within 500 m were destroyed. 8,000 houses were damaged. 2 craters about 10 m deep were created.	161	3,000	An oil tanker collided with two freight trains loaded with AN. The official position is that the incident was due to human error.
23.	Romania	Mihai road	24 May 2004	AN	20	A crater 6.5 m deep and 42 m in diameter. The city's electricity network, 16 houses, 6 cars and 2 fire engines were damaged.	18	11	The lorry overturned, a fire broke out in the cabin and spread to the cargo, which then exploded.
24.	China	Shen-gangzhen	12 September 2005	AN	19.5	Crater 5.6 m deep and 18.5 m in diameter.	12	43	It is unclear what caused the truck to explode.
25.	Mexico	Monclova, Coahuila	9 September 2007	ANFO (AN containing fuel oil)	25	A crater 9 m wide and 1.8 m deep has been created.	28	250	The driver of a van lost control and crashed into a lorry carrying AN. The accident resulted in a fire, followed by an explosion.
26.	United States	West, Texas	17 April 2013	AN	36–55 + 90	A crater 23 m wide and 3 m deep was created. 350 buildings were damaged and 142 destroyed.	15	260	According to some sources, more AN than allowed was stored in the facility. At the time of construction, the surrounding land was vacant and over the years has been built up and inhabited.

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