MARSH JLT SPECIALTY

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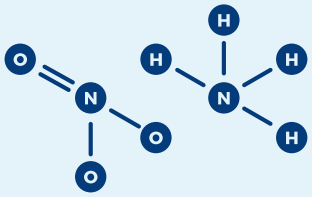
Ammonium Nitrate Explosions – Learning and Applying Lessons From the Past

This paper raises awareness of the risks, looks at the lessons learnt, and provides initial guidance on the documents and regulations available for the storage, handling, and transfer of ammonium nitrate.

The tragic incident at the Port of Beirut is widely reported to have been associated with the bulk storage of 2,750 tonnes of ammonium nitrate, which had been present since 2013, after confiscation from an impounded cargo vessel.

Such a loss refocuses the attention of the public, regulators, and other stakeholders, such as the insurance industry, on what organisations that manufacture and store ammonium nitrate can do to prevent other similar incidents.

What is Ammonium Nitrate?



Ammonium nitrate, a white crystalline solid, is an inorganic chemical compound with the chemical formula $(NH_4)(NO_3)$. It is used predominantly as a high nitrogen fertiliser, and as a component of some explosives. Ammonium nitrate is a powerful oxidiser that releases a large amount of energy when exposed to severe shock or subjected to high temperatures in confinement. The risk of an explosion is increased by a combination of heating, contamination, and confinement.

Ammonium nitrate is a hygroscopic substance – that is, it readily absorbs moisture from the air, which, if not packaged correctly, can lead to an aqueous solution forming, further increasing the risk of explosion.

In terms of risk profile, an important distinction needs to be made between ammonium nitrate and other nitrogenous fertilisers such as urea (CH_4N_2O). Urea is an entirely different compound with its own unique properties.

Putting into context the explosive nature of ammonium nitrate, 1,000 kilograms of ammonium nitrate is typically considered as having the equivalent up to 250 kilograms of trinitrotoluene (TNT) when stored in bulk, although this can vary depending on nitrogen content and other circumstances.

This paper considers challenges and controls required for the storage of solid fertiliser grade ammonium nitrate with a nitrogen content greater than 28%.

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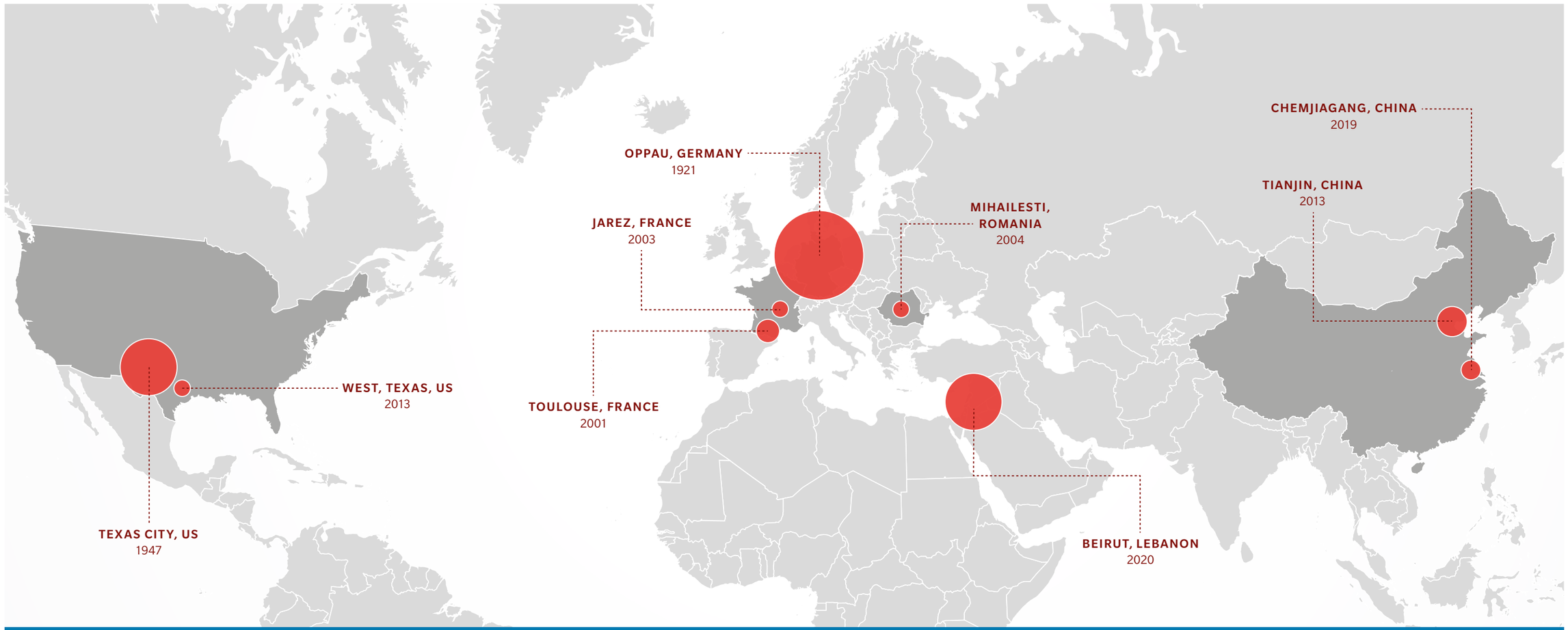
FIGURE 1

Ammonium nitrate explosions have occurred across the world.



OPPAU, GERMANY, 1921

Adjusted related costs totalled approximately US$90 million. Approximately **4,500 tonnes** of ammonium nitrate was stored; there were more than 500 fatalities, with buildings damaged up to 25 kilometres away. Contributing factors were poor storage, proximity to urban areas, and a lack of understanding of the risks associated with ammonium nitrate.

TEXAS CITY, US 1947

Adjusted related costs totalled approximately US$1.1 billion. Approximately **2,100 tonnes** of ammonium nitrate was stored, resulting in 400–600 fatalities and approximately 4,000 people injured. Contributing factors were poor storage, contamination, and a lack of understanding of the risks associated with ammonium nitrate.

TOULOUSE, FRANCE, 2001

Related costs totalled approximately US$1.4 billion in 2007. Approximately **300 tonnes** of ammonium nitrate was stored. The explosion measured 3.2 on the Richter scale, and led to 30 fatalities and approximately 3,000 people injured. Contributing factors were poor storage, contamination, and proximity to urban areas. The Seveso II Directive was extended to include ammonium nitrate following this incident.

TIANJIN, CHINA, 2013

(Involved multiple chemicals, including ammonium nitrate) related costs totalled US$9 billion. Approximately **800 tonnes** of ammonium nitrate was stored, and the explosion measured 2.3 on the Richter scale. There were 173 fatalities and approximately 797 people injured. Contributing factors are not fully understood.

WEST, TEXAS, US, 2013

Related costs totalled approximately US$260 million. Approximately **40–60 tonnes** of ammonium nitrate was stored, resulting in 15 fatalities and approximately 260 people injured. The explosion measured 2.1 on the Richter scale. Contributing factors were poor ventilation, storage with combustible materials, and a lack of understanding of the risks associated with ammonium nitrate.

CHEMJIAGANG, CHINA, 2019

Related costs totalled US$800 million and the explosion measured 2.2 on the Richter scale. There were 80 fatalities and around 640 people injured. Building damage occurred up to three kilometres away. Contributing factors are not fully understood.

The recurrence of such explosions indicates that lessons from the past are either not being learnt, or are being forgotten, and a greater industry focus is required to prevent similar tragedies in future.

In some cases, the incidents have led to the publication of guidance that outlines good practice in regulation; land planning; storage and handling; housekeeping; fire precautions; security; and employee competency. Each of these key issues is explored in this paper.

Regulation

It is important to engage governing bodies applicable to your location, and confirm you have all the necessary regulatory permits to operate an ammonium nitrate facility. Familiarise yourself with any updates to applicable codes and standards relating to the operation of ammonium nitrate facilities.

Excellent guidance on the subject is provided by documents such as the National Fire Protection Association's *NFPA 400, Hazardous Materials Code, 2019;* the UK Health and Safety Executive's (HSE's) *INDG230 Storing and handling of Ammonium Nitrate;* the EPA OSHA-ATF guidance, *Chemical Advisory – Safe Storage, Handling, and Management of Solid Ammonium Nitrate Prill;* and the government of Western Australia's *safe storage of solid ammonium nitrate* (Third edition).

A positive approach to compliance is to encourage and welcome audits and inspection from external bodies, including regulators, on a regular basis.

Land Planning

Ensuring a facility that produces, stores, or receives ammonium nitrate is not located close to urban areas is vital to preventing the escalation and impact of an incident. When construction planning starts, consideration of the industrial sites' location must form part of the assessment, before permission to construct is provided. Guidance should be sought from government legislation – the Seveso III Directive and the UK Planning (Hazardous Substances) Regulations 2015, being two good examples.

Storage and Handling

The ammonium nitrate storage area is of paramount importance. Its construction should minimise the risk of contamination, exposure shock, confinement, and heat sources. This should include the following steps:

- Construct the storage area and packaging using non-combustible materials.
- Consider subdividing the building into storage bays of convenient shape and dimensions.
- Clearly mark the designated area.
- Ensure the storage area is well-ventilated, and consider outside storage in or close to urban areas.
- Do not operate direct heaters within the storage area.
- Seal electrical fittings so to not allow ammonium nitrate dust ingress.
- Prohibit smoking in all storage areas.
- Review separation distances to critical infrastructure, residential buildings, commercial buildings, and industrial plants.
- Ensure packaging is free of defects to prevent the absorption of moisture from air or other water sources.
- Minimise open floor drains, pits, or inherent low points where aqueous ammonium nitrate could accumulate. Direct any drain away from the storage area to an unconfined open area.

When ammonium nitrate is stored in bulk in piles, the piles should not exceed 12 metres (40 feet) in height, and should be no higher than one metre (40 inches) below the roof. In general, stacks should not exceed 300 tonnes, although this limit may be raised at purpose-built stores. Where possible, piles of ammonium nitrate should be protected from absorbing moisture from humid air, by covering them with water-impermeable sheeting or using air conditioning.

Storage in stacked bags, drums, and other containers should not exceed a height of six metres (20 feet), width of six metres (20 feet), and length of 15 metres (50 feet), unless the building is of non-combustible construction or protected by automatic sprinklers.

The distance between adjacent piles or stacks should be at least one metre (40 inches). The same distance should also be maintained between piles/stacks and the walls, roof, or any electric lights or heating pipes.

Each ammonium nitrate pile or stack should be clearly identified as such. Labelling of ammonium nitrate piles/stacks with initial date of storage is advisable for auditing.

Housekeeping

The storage area must be kept clean. It is recommended that ammonium nitrate storage areas have a robust cleaning schedule, with clear guidance for personnel. This should include the following points:

- Avoid contamination of ammonium nitrate with combustible materials or organic substances, such as packing materials, dust, seed, oils, and waxes.
- Always remove all combustible material (for example, unused pallets or oil) from the storage area.
- Only store ammonium nitrate in the designated area – there should be no other products or materials.
- Immediately dispose of ammonium nitrate-contaminated waste in line with local regulations.

Ideally, the transfer of ammonium nitrate product in the first instance should be by a conveyor system, constructed of non-combustible materials. If this option is not available, use of electrical-powered transport vehicles – for example, fork lift trucks – is recommended to minimise the risk of diesel/oil spills.

Where fuel-powered transport vehicles are used, clear guidance and controls must be in place to minimise the introduction of conditions that can lead to an incident – for example:

- Oil spill kits.
- Remove vehicle from the area when not in use.
- Inspect and maintain vehicles regularly to ensure they are fit for use.
- Use of mandatory pre-use checklist to identify any defects.

Fire Precautions

Buildings should be equipped with an approved fire detection system, including, but not limited to, a smoke or heat detection system.

Consider the need to install a fixed water deluge system. If storage of ammonium nitrate is greater than 2,500 tonnes, then a sprinkler fire water system should be installed; consider the NFPA 13 and 230 standards for guidance. Fire water supply primary control should be automatic, initiated by a detection system, and equipped with manual control.

If a fire was to break out at a facility, it is important to keep the ammonium nitrate stacks as cool as possible, which requires a substantial fire water supply. A well-ventilated storage area will allow the dissipation of heat and reaction products produced in the decomposition of ammonium nitrate, which, if confined, fuel the combustion mechanisms leading to explosion.

Equip storage areas with water run-off drains to cope with the volume of water. Encourage local fire brigades to visit the ammonium nitrate storage facilities, to gain an appreciation of the hazards of ammonium nitrate, understand the fixed fire protection systems in place, and to carry out exercises into how they would fight a fire should one occur.

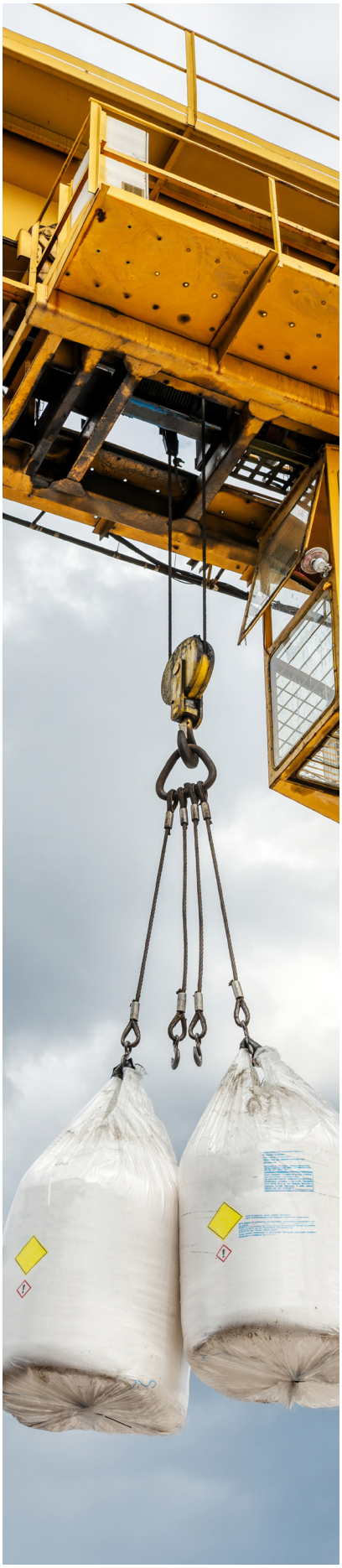
Security

Secure the perimeter around an ammonium nitrate storage area, to ensure only authorised personnel can enter by way of gate and ID entry. The area perimeter and storage area should be monitored at all times. Greater detail can be found in the UK government online guidance document, *Secure your fertiliser.*

Employee Competency

All employees and contractors involved in operating an ammonium nitrate storage facility – that is, security, maintenance, transfer, or cleaning personnel – should be trained in the hazards of ammonium nitrate, and, where appropriate, made subject to security background checks. Employees should have guidance for inspection and repair – that is, the secondary bagging of ammonium nitrate product packaging.

Onsite and local emergency response support teams must be aware of the hazards associated with fires at facilities containing ammonium nitrate through specific training.



Understanding the Facility

A checklist is a simple and effective tool for assessing if an area is meeting the standards to which you operate. Below is an example checklist for the storage of ammonium nitrate, similar to that used by the UK HSE.

If you answer **YES** to any of the questions below, you must ensure the issues are resolved. If required, seek advice from the government body or regulator applicable to the storage area location.

Ammonium Nitrate Storage and Handling Checklist

QUESTION	YES	NO
Regulation		
Are any permits relating to operation of your facility missing or out of date?		
Are any actions relating to regulatory, standard, or code updates incomplete?		
Are any actions from external or internal audits incomplete?		
Land planning		
Are occupied buildings within the blast radius?		
Have any new buildings or occupied areas – for example, parks – been constructed in the area since your operation started?		
Storage and handling		
Has the calculated maximum capacity for ammonium nitrate storage been exceeded?		
Are any material safety data sheets missing?		
Is the building or floor constructed of combustible materials?		
Is the floor in poor condition – for example, are there large cracks or holes?		
Is the ventilation system in poor condition – for example, is it restricted or an element not working?		
Are there any heat sources within the storage area?		
Are ammonium nitrate piles stacked in a way that does not confirm with the regulatory guidance for spacing?		
Is the storage area without an authorised inventory list?		
Is the building used for storing materials classed as incompatible with ammonium nitrate?		
Are other materials in the storage area poorly segregated from ammonium nitrate, and do they have missing material identification signs?		
Is the ammonium nitrate packaging constructed of combustible materials and showing evidence of defects – for example, tears or holes?		

Are ammonium nitrate packaging labels missing or without information – for example, UN number or date of storage?		
Has any ammonium nitrate exceeded the agreed time limit storage?		
If produced, can aqueous ammonium nitrate solution flow or collect in a confined area near the bulk ammonium nitrate storage area?		
Housekeeping		
Is there any loose ammonium nitrate?		
Is there evidence of spillages – for example diesel/oil?		
Are any loose pallets, metal objects, cylinders, or items not detailed on the building inventory list in the storage area?		
Are any pallets or equipment contaminated with ammonium nitrate?		
Fire precautions		
Are any employees unaware of the no smoking policy or are there any warning signs missing?		
Are there any defects in the firewater and sprinkler systems that prevent full operability?		
Are any fire water system operational checks incomplete or out of date?		
Are any electrical systems/fittings constructed to a standard that does not prevent ingress of ammonium nitrate dust?		
Are there any sources of ignition in the building not controlled under permit to work system?		
Security		
Are there any defects on perimeter fence?		
Are the entry and exits points to storage area uncontrolled?		
Do any persons onsite not have an identification card?		
Are any doors/shutters/gates/barriers open that should be closed?		
Is your facility without pest control?		
Employee competence		
Are any persons working on site without induction?		
Are any staff or contractors on site without relevant training for their role?		
Are any persons on site without completed background checks?		

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