Ammonium Nitrate explosion – Beirut, 4 August 2020

Q&As

What is ammonium nitrate?

Ammonium nitrate is a salt which takes the form of a white crystalline solid, not too different in appearance from common table salt (sodium chloride). It is found naturally but is made in large quantities by reacting the gas ammonia with nitric acid. In itself it is quite innocuous, being non-poisonous like sodium chloride and stored properly (in water-tight containers) is relatively stable but it is very hygroscopic which increases the potential of the molecules to absorb moisture from the surrounding environment. Its main applications are as a fertiliser, in pyrotechnics, herbicides and insecticides, and in the manufacture of nitrous oxide. It is used as an absorbent for nitrogen oxides, an ingredient of freezing mixtures, an oxidizer in rocket propellants, and a nutrient for yeast and antibiotics. It is also a component in explosives used in mining and, by the military. There have also been instances of the product being diverted from legitimate uses for terrorism purposes.

Is it explosive?

If kept isolated and unconfined, it is quite stable. If in an open space where the heat can escape, if heated it decomposes to oxides of nitrogen (which are a health hazard) and water vapour but will not catch fire. However, if it comes into contact with an intense source of heat and ignition, such as a detonator or an intense fire for some time, and is present as a large bulk mass (e.g. confined within containers or sacks, which may themselves be flammable) and in a confined space, such as a warehouse, then it can explode. It will also explode if contaminated or mixed with combustible materials such as fuel oil. It decomposes rapidly to gases, because of the confinement heat cannot escape, the gases rapidly expand, and the explosion occurs. This releases an enormous amount of energy and sends out a shock wave as the surrounding air is rapidly compressed which propagates very rapidly over the surrounding area and can cause enormous damage to buildings and people. Thermal decomposition of ammonium nitrate occurs over 200°C but the presence of organic and metallic impurities can reduce this temperature. Once it starts to decompose, a runaway reaction may occur as the heat of decomposition increases.

What happened in Beirut?

From the footage there was initially a large cloud of what looks like white/grey smoke from behind the white building which may have been the storage warehouse. This indicates that there may have been a fire close to or even inside the store, which was probably the source of heat (and maybe of ignition for flammable packaging) which set off the explosion of the 2,750 t of ammonium nitrate reportedly stored there. When the explosion happened, a new mushroom-shaped cloud rapidly developed and expanded rapidly over a wide area, inland over the port and out over the water. This has an orange, red/brown colour which is characteristic of nitrogen dioxide, one of the decomposition products of ammonium nitrate, which is a very good indicator that this substance was involved and the likely source of the explosion. The mushroom type cloud is formed by the rapidly expanding gases which rise upwards as they are heated and so have a lower density than the surrounding air. They rise in the stem of the mushroom and then because they are rising very quickly give rise to turbulent instabilities inside the cloud which give recirculating air/gas regions at the top which cause the cloud to balloon out and have its characteristic mushroom shape. The pressure shockwave radiates outwards through the air much more quickly and its effects are felt much further away within seconds. You can see buildings razed to the ground instantly when the pressure wave reaches them.

How would the storage of the chemical have affected the explosion?

The material was onboard a ship that was seized by the port authority in February 2014 and then stored for some six years or so. It could be that long-term storage had caused some deterioration of the ammonium nitrate and made it more susceptible to explosion. For instance, if the storage was not airtight, in the humid conditions of Beirut, the salt could have taken up large quantities of water from the air which would cause the granules and pellets to fuse over time into a large consolidated mass from which heat and gases from the decomposition could not escape as easily as from a dispersed granular, free-flowing pile of fine particles. This would have just added to the confinement effect which increased the risk of an explosion once a source of heat was applied.

Have there been any other ammonium nitrate explosions?

Ammonium Nitrate fires are notorious – they seem to occur every 10-20 years, causing major loss of life and widespread damage.

There have been several accidents and a few disasters in the ammonium nitrate fertiliser industry, and it is worthwhile to review these from time to time, beyond the regulation and practice changes which they triggered.

On 21 September in 1921, two consecutive explosions occurred in a silo in the BASF plant in Oppau, Germany, creating a 20m deep, 90x125m large crater. The entire area was covered by dark green smoke and there were several additional fires and small explosions. At the time of the event 4,500 t of ammonium sulphate nitrate compound fertiliser (ASN) were stored in the silo. The explosion killed 507 people and injured 1,917.

Another tragic accident, involving two ships loaded with thousands of tonnes of ammonium nitrate and sulphur, occurred on 16 April in 1947 on the ship SS Grandcamp docked in Texas City, Texas, USA. In that event, 500 people died and 3,500 people were injured, which was 25% of Texas City's population at the time.

Exactly 80 years to the day after Oppau, a severe explosion occurred in a temporary storage for off-specification and downgraded ammonium nitrates at 10:17 on 21 September in 2001 at the AZF industrial site in Toulouse, France. The detonation, felt several kilometres away, corresponded to a magnitude of 3.4 on the Richter scale. A 7 m deep crater (65 m x 45 m) was observed outside the plant and a large cloud of dust and red smoke drifted to the north-west. The accident resulted in 30 fatalities, with up to 10,000 people injured and 14,000 people receiving therapy for acute posttraumatic stress. The cost was estimated by insurers to be in the region of 1.5bn Euro.

More than 60 years after the Texas City disaster, a significant explosion of fertilisers shook the inhabitants of Texas again. On the evening of 17 April 2013, a fire of undetermined origin broke out at the West Fertilizer Company in West, Texas, USA. After their arrival, firefighters started to fight the fire when a detonation occurred. Although the firefighters were aware of the hazard from the tanks of anhydrous ammonia, they were not informed of the explosion hazard from the 30 t of fertiliser grade ammonium nitrate with a 34% total nitrogen content, which was stored in bulk granular form in a 7 m high bin inside the wooden warehouse.

Have there been lessons learnt from these accidents?

While there have been many investigations and lessons determined, there is a challenge with translating these lessons into institutionalised learning. The findings from the Toulouse accident resulted in changes to European legislation via the Seveso II Directive, firstly in 2003 with a change of classification criteria for ammonium nitrate, ammonium nitrate-based fertilisers and off-specification materials.

In addition, unless the safety precautions are improved and permanently monitored, and there is a change in culture to accept that this is a continuous process that requires constant vigilance, not just putting in place a few improved measures at the time.

The unique safety challenges associated with ammonium nitrate coupled with poor safety management culture could largely be considered as the most important contributing factors across the accidents. Insufficient fire prevention, protection and control systems were also common in these accidents. One of the biggest problems in these past events was the lack of knowledge of the inherent hazards associated with the handling and storage of ammonium nitrate.

It is important to store ammonium nitrate in separate fire divisions from highly combustible commodities in a well-segregated, well-ventilated non-flammable structure. When there are population centres nearby, provisions of land-use planning should be considered. It is recommended to store ammonium nitrate outside in smaller quantities, isolated from sources of heat, combustion, hot work (operations involving open flames or producing heat and/or sparks, such as welding) and impurities or potential contaminants such as fuel oil.

Despite lots of experience with these accidents, global learning is poor. As well as putting much better safety mitigation measures in place and making company management embrace a top-down safety culture, communication between manufacturers and users of these and similar materials across the world is very poor – largely because ensuring the users know about all the lessons from the past and bring in best practice is still not widespread practice.

What will IChemE do to support process safety improvements in the future?

As a learned society for chemical, biochemical and process engineers, IChemE will seek to understand the learnings from the disaster and where appropriate incorporate them into future process safety guidance to improve safety practices that will help protect the public and serve society.

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