Incident

Port of Beirut — lessons from the ammonium nitrate explosion that devastated the peninsula

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Summary

On 04 August 2020, Port Beirut saw what was to be one of the biggest ammonium nitrate explosions since 2000, when 2,750 tonnes of stored Nitropril™, equivalent to 1.3 kt of TNT[1], was detonated. With a death toll of 207 people and 7500 injured[2,3] and $15 billions of reported property damage[4], the disastrous incident ranks amongst the top ten of the largest accidental explosions, and attracted the attention and scrutiny of political, humanitarian, and scientific groups across the world. This was not the first chemical hazard involving ammonium nitrate, and there were significant failings to adopt the appropriate safety protocols to prevent the resulting explosion.

Keywords: Beirut, ammonium nitrate

Ammonium nitrate — the catalyst for disaster

Ammonium nitrate is a chemical compound that is manufactured when ammonia gas is reacted with liquid nitric acid. Widely used in agricultural applications as a fertilizer along with other applications in the manufacture of mining explosives, ammonium nitrate is a highly combustible compound when combined with oils or other fuels, or when exposed to extremely high temperatures (temperatures should not exceed 210°C); therefore, transport and storage should be planned and implemented with these parameters in consideration.

Ammonium nitrate is considered an oxidiser, classified under the GHS of Classification and Labelling of Chemicals as a Class 5.1 oxidising substance[5]. This means that at an atomic level, it removes electrons from other substances in a chemical reaction. As an oxidiser, ammonium nitrate possesses the ability to increase the burning of fuels by increasing the oxygen that is available to those fuels, hence its applications in explosives manufacture.

Ammonium nitrate must encounter an open flame or other ignition source to spark a reaction; once it does, it explodes violently[6]. Nitropril™ is a technical-grade, explosive variant of ammonium nitrate. Based on the manufacturer's safety data sheet[7], Nitropril™ is specifically designed to be used as an oxidiser in blasting agents. Storage requirements include that it be kept dry, away from ignition/heat sources, and stored in well-ventilated areas[8].

What set the disaster in motion?

Timeline

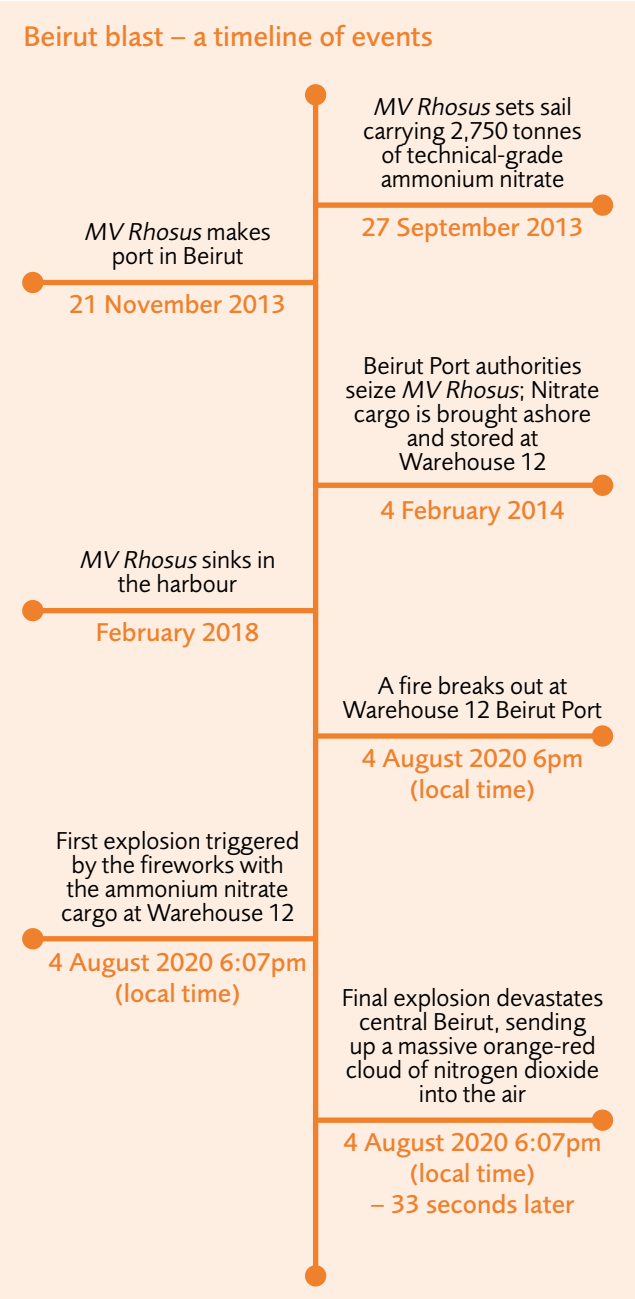

Figure 1 – A simplified timeline of events leading to the explosion

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Even though the explosion took place in 2020, the events that set the disaster in motion took place years prior.

In September 2013, Moldovan-flagged ship *MV Rhosus* set sail from Batumi, Georgia enroute to Beira, Mozambique[9], carrying 2,750 tonnes of technical-grade ammonium nitrate. When the ship made port in Beirut, an inspection by the port state control deemed the ship unworthy and forbid it to set sail[10]. Due to unpaid fines, the Beirut Port authority seized the ship, with the ammonium nitrate cargo being brought ashore and stored at Warehouse 12, where it remained for the next six years.

Disaster struck on 04 August 2020, at 6 p.m. local time, when a fire broke out at Warehouse 12. A team of nine firefighters and one paramedic (Platoon 5)[11] were sent to control the fire. However, the fire ignited some fireworks that were stored with the ammonium nitrate cargo, triggering the first explosion and sending up a huge cloud of smoke[12]. Only 33 seconds later, the final explosion devastated central Beirut, sending up an orange-red cloud of nitrogen dioxide (a by-product of ammonium nitrate decomposition) into the air. This explosion was destructive and substantial, with shockwaves being felt in Turkey, Syria, Israel, parts of Europe, and Cyprus[13]. The detonation at Warehouse 12 also caused a chain reaction, when a nearby ship, also carrying ammonium nitrate, exploded, setting fire to chemical tanks and oil refineries near the port.

Appeals to government

The ammonium nitrate cargo was stored in a light-skinned general cargo warehouse, which was inappropriate for the storage of dangerous products due to its location, construction standard, environmental protection, and security measures[7]. The port authorities, aware of the risks of storing technical-grade ammonium nitrate at the warehouse that was not adapted to the storage conditions required by ammonium nitrate[7], lacked the resources and court approval required to move it to a more suitable facility more in-line with the safety guidance.

According to an investigation conducted by the General Directorate of State Security[14], port officials had warned of the dangers of storing enormous amounts of explosive chemicals at the port through several letters, including a private letter to President Aoun and PM Hassan Diab on July 20, 2020[14], warning of the dangers of security risk and requesting its removal at least six times[15], but this advice was not heeded.

It had been repeatedly advised by Lebanese customs officials in letters regarding the issue of the confiscated cargo, that the ammonium nitrate be either exported, given to the Lebanese Armed Forces, or sold to the private Lebanese Explosives Company[16]. One of the letters sent in 2016 noted that judges had not replied to previous requests, and pleaded[16]:

> *"In view of the serious danger of keeping these goods in the hangar in unsuitable climatic conditions, we reaffirm our request to please request the marine agency to re-export these goods immediately to preserve the safety of the port and those working in it, or to look into agreeing to sell this amount."*

Warehouse interior

The interior of Warehouse 12, as mapped through examination of opensource information such as videos, photographs, and documents, by Forensic Architecture[17], a research agency based at Goldsmiths, University of London, shows 2750 bags of ammonium nitrate being stored on the floor. The reported stock of 23 tonnes of fireworks and 1000 car tyres is not visible in the picture.

It is seen in Figures 2 and 3 that ammonium nitrate was not stored in compliance with the Australian Standard AS 4326[18] as advised by its safety data sheet[7], but had been merely dumped on the warehouse floor.

Gareth Collet, an explosives expert for the UN, worked with Forensic Architecture, and stated that from an engineering point of view, the arrangement of goods within the building was the spatial layout of a makeshift bomb on the scale of a warehouse, awaiting detonation. He further added "ammonium nitrate is extremely difficult to detonate by fire alone. However, when confined and contaminated, this... can lead to catastrophic detonation. It is sensitised by the presence of even the smallest quantity of additives and hence should be separated"[17].

A comparison of the actual layout of the ammonium nitrate bags at the port warehouse was conducted with the internationally recognised standards such as INDG230[19] and AS 4326[18] standards

Causes

Through Figure 3, it is observed that fireworks and tyres were stored in close proximity to a cargo of potentially explosive ammonium nitrate, going against recommended storage instructions. The entire 2750 tonnes cargo of this explosive chemical was stored in one place, rather than being divided up and sent off to separate storage facilities to reduce the risk associated with containment.

Furthermore, there was no segregation — the entire cargo was kept in a single restricted stack. Stacked bags or sacks apply

Figure 2 – Layout of ammonium nitrate bags as recreated by Forensic Architecture[17]

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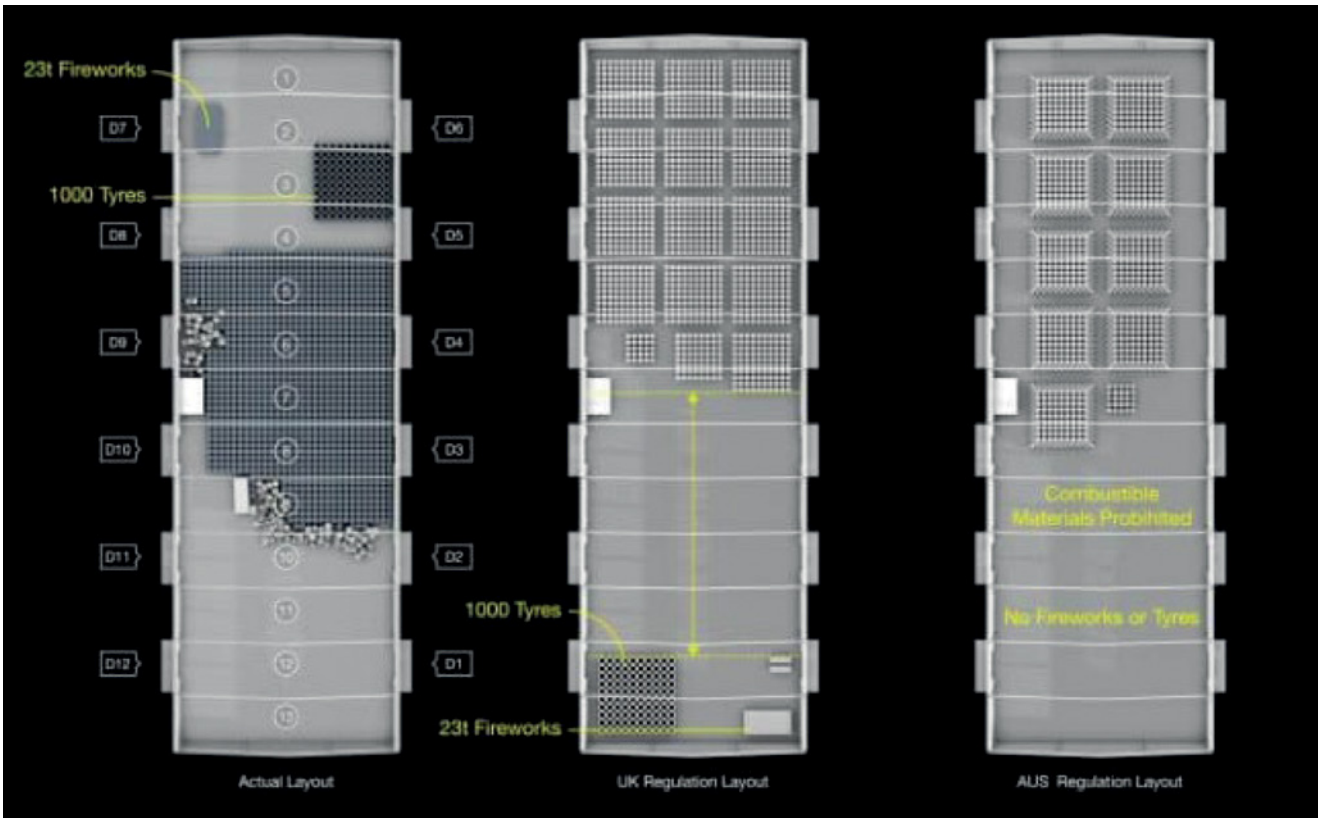

Figure 3 – A comparison of the layout of the elements stored inside Warehouse 12, and how they are required to be laid out according to the British and Australian standards[17]

static pressure to the AN, which might cause changes in the crystal structure and hence increase chemical sensitivity which would have hindered firefighting even if the fire service had timely access to the storage site in the event of a fire breaking out.

The ammonium nitrate was also directly exposed to the atmosphere during its storage, where it would have become progressively more contaminated with dust and other organic matter and would have absorbed moisture from the humid maritime atmosphere.

The failure to remove ammonium nitrate cargo from the warehouse to a more suitable storage location, combined with the inappropriate conditions in which this ammonium nitrate was stored at the warehouse, was what ultimately provided the window for disaster.

Therefore, the definitive cause was oversight; oversight by the government officials and inspection authorities, as they failed to understand the extent of the danger posed by mismanagement of safety protocols regarding storage of 2,750 tonnes of ammonium nitrate at one of the biggest commercial ports in the country bordering densely populated civilian areas. All the other causes branch out from this one crucial failure in regulating the ammonium nitrate properly. The storage of technical-grade ammonium nitrate at Beirut Port was not part of its regular operations, though many appeals by the port authorities to move the cargo were over-ruled[15, 16].

Businesses and infrastructure ruined	The blast created a 400 ft (120m) wide crater where the port used to be[30] causing an astounding $15 billion in property damage, leaving about 300,000 people homeless and 50% of businesses and service sectors damaged.
Healthcare	The healthcare sector was amongst the most critically affected, with 292 healthcare facilities damaged in the aftermath of the explosion (equating to about 36% of the healthcare facilities in the region), reducing the access and quality of medical care available[20].
Environmental impact	The blast produced enormous white and orange-red clouds[8] containing white ammonia mist (NH_3), HNO_3, H_2O vapours, and hazardous and toxic NO_x compounds nitrous oxide (N_2O), nitric oxide (NO), and nitrogen dioxide (NO_2). Nitrogen dioxide was particularly dangerous during the COVID-19 crisis, as it is known to damage respiratory systems in several ways. In fact COVID-19 cases rose from 177 on 3 August to 334 on 14 August[8]. Toxic plumes from the explosion were dispersed within 24 hours, but the long-term environmental repercussions currently remain unexplored.
Commercial panic	Concerns were raised regionally and beyond about the storage of ammonium nitrate and other similar chemicals at ports across the world[21]. Despite its dangers, ammonium nitrate demand continues to grow in the chemical industry, with an estimated 3% increase in market size by 2026[21], which makes it more imperative than ever to enforce proper safety, handling, and storage regulations.

Table 1 – Impact analysis of the Beirut explosion

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Impact analysis of Beirut explosion (see Table 1)

Lebanon was undergoing a huge economic crisis (caused by local civil wars and a refugee crisis due to wars in neighbouring Syria), causing a rise in poverty and unemployment rates and massive inflation. This crisis was already worsened by the COVID-19 pandemic, and combined with the aftermath of the explosion, there is considerable strain on the government, healthcare systems, banks, and individuals.

Hazard prevention and risk control

Most of the time, the root cause of a chemical accident or disaster is lack of awareness of the hazards and inappropriate measures to control the risks, rather than equipment failure.

It is obvious that Lebanon has a chemical storage problem, not only looking at the Beirut explosion, but also the fire at Beirut Port on 10 September 2022[22, 23] caused by the ignition of a tyre and oil store, injuring at least 14 people, along with the hazardous chemical clean-up operation that led to the discovery of at least 59 containers of dangerous chemicals[24,25] abandoned at warehouses like the ammonium nitrate cargo. There is a desperate need for a national Chemical Regulatory Agency in Lebanon to oversee and implement chemical safety measures and adopt preventive strategies for chemical industries across the entire country.

Lebanon does not currently have legislation specific to ammonium nitrate handling and storage. The handling and storage of hazardous chemicals is regulated by Decree No. 11802 of 2008 on Occupational Health and Safety[26], which provides the standard Health & Safety measures for any workplace, covering ventilation, passageways, storage building specifications, warning signs, and training. Ammonium nitrate is categorised as an explosive under the Legislative Decree No.137 regarding weapons and ammunition[27]. Chapter 5 of this decree prohibits possession or sale of explosives without proper licenses, with Article 53 instructing special warehouses to be established to store explosive materials. Additionally, Law No. 444 of 2002 on Protection of the Environment (Part VII) requires a permit to be obtained for the import and storage of dangerous materials or chemicals[28].

Legislation can, however, only be drafted and enforced properly through organised governmental action: The prevention and control steps identified will offer an essential point of discussion for government officials and policymakers to build and implement an effective chemical safety framework that not only includes regulation and storage protocols, but also guidance on emergency services and disaster preparedness, which will prevent such disastrous incidents from taking place in the future, but top-down management with connectivity and efficient information-flows should be implemented to monitor industrial and chemical operations. Co-ordination between private-sector and industries should be strengthened to avoid gaps in national regulatory frameworks.

Conclusion

Past incidents have shown that ammonium nitrate is not always stored appropriately, and amongst accidents involving ammonium nitrate, the leading cause has been uncontrolled fire due to ignition of the stockpile[8]. But ammonium nitrate cannot be ignited by itself, and its trigger usually lies in storage and surrounding conditions.

The explosion in Beirut, was a combination of inappropriate storage conditions, and a lack of oversight by the government and intransigence by the courts towards addressing the safety concerns which had been raised.

Therefore, in legislative drafting, a priority should be given to developing policies that enforce application of recognised standards and regulations, along with good governance and responsibility, in storing ammonium nitrate. Port areas should be developed and prepared to manage hazardous cargoes which they are required to store but are not part of their normal planned operations.

The key lesson here is that disaster prevention is not just about preventing importers and distributors from storing large amounts of chemicals improperly; hazards and risks are now present throughout the industrial supply chain.

There should be an effective organisational structure and communication in place at the site to ensure all safety procedures are being followed. There is an also essential need of good leadership and effective government policies along with detailed chemical safety procedures, to attain world-class safety performance. Organisations should augment their systematic risk-based policies with pragmatic measures. The goal should be to design a system that is resilient and does not collapse due to human error.

The only way to prevent chemical incidents such as the Beirut explosion is to take a rigorous, collaborative approach to safety. It is necessary for government officials and policymakers to take a proactive and collaborative approach to develop national legislation and regulations to implement chemical safety measures, including their storage, handling, and transport, along emergency preparation in response to any small- or large-scale incidents.

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