SIESO Medal paper

Failures, repeated – the Tianjin explosion

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Summary

On 12 August 2015, the port of Tianjin became the epicentre of one of the world's largest artificial, non-nuclear explosions[1]. Tragically, 173 people, including 104 firefighters, lost their lives in a series of explosions — the largest of which registered the seismic activity of a 2.9 magnitude earthquake[2]. The doors and windows of 17,000 households were destroyed. Chemicals including sodium cyanide were dispersed and contaminated water drained from the site. Residents within 3km were evacuated due to the risk of toxins leaching into the potable water systems. Mishandling and incorrect storage of nitrocellulose allowed the compound to spontaneously combust. Multiple systemic and cultural failings have been implicated as root causes. This article outlines the events that led to the explosions, and some of the lessons learned from the accident.

Keywords: Explosion, nitrocellulose

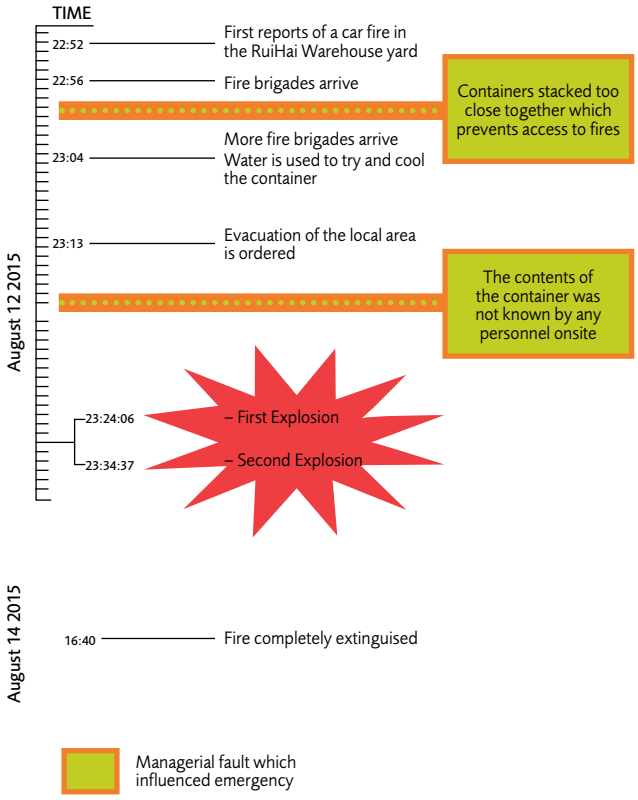

Figure 1 – Timeline of Explosions

The Tianjin explosions

The port of Tianjin, situated 120 km from Beijing, is one of the world's largest and busiest ports with an annual throughput of 480 million tonnes[3]. In 2011, the Ruihai International Logistics Company was established to ship hazardous chemicals quicker and more efficiently than their state-run rivals, who had previously held much of the market share[4].

On the night of the explosion, a fire was reported to the fire brigade at the Tianjin Port Public Security Building. Firefighters arrived at the Ruihai warehouse yard within four minutes of the first reports, unaware of the hazardous compounds which were being stored on the site. The origin of the fire was quickly identified as a storage container within the yard. Despite the firefighter's attempts to establish the contents of the container, a lack of documentation prevented employees from being able to inform the fire service.

The firefighters struggled to tackle the blaze as the containers were stacked too close together, obstructing access for the fire engines and allowing the fire to grow. Just after 11 pm, there was a call to evacuate the site and all surrounding buildings. The first explosion occurred 30 minutes later sending a shock wave through the New Binhai Area. A second, larger explosion occurred 30 seconds later, destroying the doors and windows of 17,000 households and resulting in six large fires that took a further 41 hours to extinguish[1]. The timeline of the explosions is illustrated in Figure 1.

The following day, military personnel arrived to assist in the search and rescue effort. Additionally, 200 chemical experts were deployed to assess the extent to which toxic chemicals were released into the local environment. To facilitate this, twelve temporary monitoring stations were set up, all of which recorded dangerously high levels of pollutants, with one station showing the sodium cyanide levels were 356 times higher than the safe limit[5]. On the afternoon of 13 August, firefighting efforts were paused to allow the chemical experts to accurately assess the hazardous chemicals onsite[6].

Nearly 700 tonnes of sodium cyanide were discovered on-site, therefore, the removal and detoxification using hydrogen peroxide became of the utmost importance[7]. The cyanide concentration within draining water was found to be three to eight times higher than the allowable maximum[8], thus, to prevent pollutants from discharging to the sea, concrete was used to block two drain outlets. Due to the threat of toxic chemicals leaching into the potable water systems of Tianjin, all residents within a 3km radius of the Ruihai Logistics yard were evacuated[9].

Causal chain

From the information available, it is concluded that the chain of events started when one or more containers of nitrocellulose overheated. This resulted in the wetting agent, used to keep

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it stable, evaporating. Further heating led to spontaneous combustion[4].

The fire spread to a sizeable quantity of ammonium nitrate being stored nearby, causing two explosions in quick succession approximately 30 seconds apart[1]. Other chemicals being stored in the area may have triggered the detonation more readily[3, 4].

The destruction caused by the explosions was immense but immediate. Knock-on effects from other chemicals being dispersed as a result led to the longer-term issues of contamination[3]. Inadequate emergency response inevitably contributed to the outcomes[4].

Conclusions

The substances involved in this incident are all widely used globally. They are hazardous but this is recognised, and effective controls are well known. From the details known about this accident, it can be concluded that:

- Materials were not being stored in the correct conditions: Nitrocellulose was either not being kept adequately wet and/or was not protected from sources of heat.
- Different materials were being stored too closely together[10]: The larger second explosion involving ammonium nitrate was triggered by the nitrocellulose[1]. Sodium cyanide was dispersed by the explosions causing widespread contamination[3].
- Residential buildings and hazardous storage were built in close proximity[3] and quantities of hazardous materials being stored were far in excess of those officially permitted[4].
- The emergency response was ineffective at protecting people from harm[4].

Overall, there appears to have been multiple failures to adopt known safety measures. This suggests a lack of understanding of the hazards or knowledge of accepted controls. It implies a poor safety culture that may have been contributed to by poor regulation. It is widely reported that operations were being conducted illegally[4].

Preventative measures

In the immediate aftermath of the explosion, the government ordered a national inspection of all hazardous material storage sites, with 10,269 enterprises suspended whilst they improved their safety standard[11]. Of these, 2,550 were permanently shut down with safety concerns cited as the predominant issue. At the same time, 926 people were placed under criminal investigation for breaches of health and safety laws. In the following month in 2015, major accidents in the chemical industry decreased by 40 % from the previous year[11] with this reduction being accredited to the clampdown in regulation enforcement.

The months that followed contained plans from local Chinese bodies to upgrade or relocate around 1,000 existing chemical plants to meet existing regulations. This was estimated to be at a cost of around £40.6 billion[12]. Lastly, the government made new requirements for the linkage between the chemical industry and public safety officers, in the hope of streamlining communication between agencies.

Essential learnings and further actions

Applying learning from previous major accidents should be effective at reducing the likelihood of a similar reoccurrence in the future. Improving the safety culture within industrial companies should be undertaken to inform employers of their roles and responsibilities. The regulatory system should be improved in a coordinated and consistent way, this would allow a fair allocation of responsibilities regarding permit observation and enforcement. Strengthening the supervision from intermediate service agencies should increase compliance. Finally, training and planning for emergency services in dealing with hazardous chemical fires could save lives.

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