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Review / Przegląd

Good practices in managing the risks associated with the storage, handling and transportation of ammonium nitrate(V) in the light of the Beirut explosion in 2020
Dobre praktyki w zarządzaniu ryzykiem związanym z przechowywaniem, przeładunkiem i transportem saletry amonowej w świetle wybuchu w Bejrucie w 2020 roku

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Abstract: *The explosion that took place on August 4, 2020 in the port of Beirut recalled the devastating effects of accidents involving chemicals. The incident started with a fire which spread to the port storage area and caused the explosion of 2750 tons of ammonium nitrate(V) (AN) stored there. The explosion resulted in the death of over 200 people. About 6,500 people were injured and 300,000 people had to be displaced due to the devastation it caused. Critical infrastructure, including the port area and healthcare facilities, was severely damaged. Unfortunately, serious accidents involving AN or fertilizers based on AN are taking place despite growing awareness of chemical and process safety.*

The paper discusses the conclusions drawn at the Seminar organized by the United Nations and the Organisation for Economic Co-operation and Development with regard to the causes of the Beirut disaster. International experts presented instruments and legal guidelines to prevent, prepare and respond to industrial accidents involving hazardous substances, including AN-based fertilizers, and the steps to be taken to strengthen regulations in the field of accident prevention and preparedness.

Streszczenie: *Wybuch, który miał miejsce 4 sierpnia 2020 r. w porcie w Bejrucie przypomniał o niszczycielskich skutkach, jakie niosą wypadki z udziałem chemikaliów. Zdarzenie to rozpoczęło się od pożaru, który rozprzestrzenił się na obszar magazynowy portu w Bejrucie i spowodował wybuch składowanego tam w dużej ilości azotanu(V) amonu (AN). Wybuch doprowadził do śmierci ponad 200 osób. Około 6500 ludzi doznało obrażeń i 300 000 osób musiało być przesiedlonych w związku ze zniszczeniami jakie nastąpiły w jego wyniku. Poważne uszkodzenia dotknęły infrastrukturę krytyczną, w tym obszar portu i obiekty opieki zdrowotnej. Niestety poważne wypadki z udziałem AN lub nawozów na jego bazie miewają miejsce, mimo rosnącej świadomości w zakresie bezpieczeństwa chemicznego i procesowego.*

W ramach artykułu omówiono wnioski wyciągnięte na forum Seminarium zorganizowanego przez Organizację Narodów Zjednoczonych oraz Organizację Współpracy Gospodarczej i Rozwoju w odniesieniu do przyczyn katastrofy w Bejrucie. Międzynarodowi eksperci przedstawili instrumenty i prawne wytyczne mające na celu zapobieganie, przygotowywanie i reagowanie na awarie przemysłowe z udziałem substancji niebezpiecznych, w tym nawozów na bazie AN oraz kierunki jakie należy obrać, aby wzmocnić regulacje w zakresie zapobiegania wypadkom i przygotowania się na nie, w razie ich wystąpienia.

Keywords: *ammonium nitrate(V), fertilizers, regulations, Beirut explosion, major accidents*
Słowa kluczowe: *azotan(V) amonu, nawozy, przepisy prawne, wybuch w Bejrucie*

Symbols and abbreviations

AN	ammonium nitrate(V), NH_4NO_3
UN	United Nations
OECD	Organisation for Economic Cooperation and Development
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
OCHA	JEU United Nations Office for the Coordination of Humanitarian Affairs Joint Environment Unit
UNDRR	United Nations Office for Disaster Risk Reduction
ILO	International Labour Organization
GHS	Globally Harmonized System of Classification and Labelling of Chemicals
TDG	Sub-Committee Of Experts On The Transport Of Dangerous Goods
ICAO	International Civil Aviation Organization
IMO	International Maritime Organization
IMDG	The International Maritime Dangerous Goods Code
IMSBC	International Maritime Solid Bulk Cargoes Code
CLP	Regulation (EC) No 1272/2008 of the European Parliament and of the Council
MTC	Manual Test and Criteria
JRC	Joint Research Centre of the Major Accident Hazards Bureau

1. Introduction

On 4 August 2022, moments after 6:00 pm, an explosion occurred in the port of Beirut, a reminder of the devastating consequences of chemical accidents. The incident started with a fire which spread to the port's storage area and caused an explosion of the 2,750 tonnes of ammonium nitrate(V) (AN) stored there. Forensic-Architecture has developed a 3D projection of the events which took place during the disaster based on independent sources (films, photographs and documents) [1-4]. Based on photographs illustrating the layout of the main buildings in the harbour area, the location of where the fire started, was established. At 5:54 pm, the first photo was recorded with smoke escaping from the port warehouse. The fire started in the north-eastern part of the warehouse. The fire was developing rapidly. Based on photographs showing the harbour area, experts from Forensic-Architecture observed that the shape and colour of the smoke changed with every minute. Firefighters, who were on the scene minutes after the call, recorded at 5:58 pm the sound of fireworks going off, which were stored in the warehouse. The colour of the smoke changed several times during the course of the fire, suggesting that the fire was consuming further materials in the warehouse. Changes in smoke colour were observed over a 2-minute period. First to be seen at 5:45 pm was white smoke coming from the corner of the warehouse building. Subsequently the smoke became dark in colour which indicated that tyres had caught fire. At 6:07 pm, a third type of smoke was observed coming from the central part of the warehouse prior to the main explosion. Close-up photographs taken during the initial phase of the fire show that smoke was escaping through all windows and vents from the start of the incident. After a few

minutes of fire in the warehouse, the AN – 2,750 tonnes – had reached its decomposition temperature of approx. 250 °C. 45 s after the fireworks, the AN exploded. After the explosion, brown smoke was observed confirming the presence of nitrogen oxides, which reached an altitude of 755 m. The entire event lasted 14 min and led to the deaths of more than 200 people, around 6,500 people being injured and 300,000 people being displaced due to the destruction that occurred. Critical infrastructure, including the port area and healthcare facilities, was severely damaged. A projection reflecting the course of events is available at [5].

A Seminar organised by the United Nations (UN) and the Organisation for Economic Co-operation and Development (OECD) on the 2020 Port of Beirut explosion was held on 14 December 2021 [6]. The event brought together experts from around the world. It was attended by representatives of international governmental organisations, non-governmental organisations, national and local authorities, industry and industry organisations. The aim of the seminar was to:

(a) Share lessons learned from past accidents involving AN and AN-based fertilisers.
(b) Review international legal instruments and tools for prevention, preparedness and response to accidents and incidents involving hazardous substances, in particular such as AN and AN-based fertilisers.
(c) Exchange experience and good practice in the management of risks associated with hazardous substances, including AN and AN-based fertilisers and the implementation of related instruments.
(d) Encourage cooperation between authorities, industry and other stakeholders at national, regional, local and international level.

2. AN

Annual production of AN is around 49 million tonnes, of which around 20% is exported or imported. This confirms the high demand for this product in the global market. It also means that, in addition to production and use, transport and storage are also important. The industry is well-established in global markets and has a history of more than 100 years. The main application of AN is in explosives and agricultural fertilisers.

AN used in the explosives industry is mainly sold and transported between two well-regulated industries: industrial and mining. Safety issues are prioritised in this area. On the other hand, the fertiliser industry is of a different nature and poses different safety challenges. AN is a very efficient and widely used nitrogen fertiliser. Therefore, there can be at least four major players in this industry:

– AN producers,
– formulators and other processing industries,
– dealers/distributors/farmers,
– transport industry, warehouses/ports.

A number of regulations and guidelines for the safe storage of AN-containing fertilisers are widely available. Their overall message is that it is a very stable substance and the risks of explosive and oxidising properties are well known and understood. The various guidelines set out similar safety requirements – the building should be designed in accordance with recommendations (suitable for combustible materials); avoidance of contamination; effective segregation of incompatible materials, sources of ignition, heat and mechanical stimuli.

Examples of topics covered in the industry guides include:

– storage, handling and transport of solid mineral fertilisers,
– fertiliser compatibility,
– safe handling and use of fertilisers which do not comply with quality standards,
– safety and security during transport and storage of fertiliser grade AN at fertiliser retailers.

Leading organisations, speaking on chemical safety issues, indicate guidelines on conditions to be avoided or strictly controlled when marketing AN-based fertilisers. A summary of these guidelines is presented in Table 1 [7-9].

Most existing AN codes/standards/guidance sets out similar safety requirements, which include, but are not limited to:

– separation of protected areas,
– segregation from incompatible materials, e.g. fuels / combustible materials,
– avoidance of AN pollution,
– buildings designed of non-combustible materials,
– adequate fire protection,
– mandatory standards for maintenance and cleaning work.

Table 1. Conditions to be avoided or controlled for the production, trade, storage and transport of AN

Topic	Conditions according to		
	SAFEX	**IME**	**NFPA**
Heat/fire	Construction made of non-combustible materials. No combustible substances in proximity.	Buildings should be made of non-combustible materials. If combustible materials are used, fixed sprinkler fire extinguishing systems are required. Facilities must implement a programme of so-called Hot Works to ensure safety.	Buildings should be made of non-combustible materials. Where combustible construction materials are used, a fire protection system must be provided. Flammable and combustible materials must be separated from AN.
Pollution	Incompatible materials must be kept strictly separate from AN-based fertilisers.	Incompatible organic and inorganic materials must be kept away from AN.	Organic chemicals, acids, self-igniting materials, fuels etc. (detailed list available) must be separated from AN.
Mechanical stimuli	Dedicated storage space. Adequate separation from potential explosive atmospheres.	In the case of storage with explosives, it is mandatory to maintain the safe distances required by law.	Explosives and blasting agents should not be stored with AN unless permitted by NFPA 495 (Explosives Code).

3. Analysis of existing regulations and guidelines in light of the Beirut disaster

International instruments applicable throughout the life cycle of various hazardous substances, including AN and AN-based fertilisers, include:
– United Nations Globally Harmonized System of Classification and Labelling of Chemicals (GHS), Rev. 7, 2021.
– UN Recommendations on the Transport of Dangerous Goods, Model Regulations, Rev. 20, 2021.
– Agreement concerning the International Carriage of Dangerous Goods by Road (ADR), Edition 2021-2022.
– Manual of Tests and Criteria (MTC), Rev. 6, 2020.
– ICAO Technical Instructions for the Safe Transport of Dangerous Goods by Air, Edition 2017-2018.
– IMO International Maritime Dangerous Goods (IMDG) Code, Edition 2020.
– UNECE Convention on the Transboundary Effects of Industrial Accidents, Journal of Laws of 2004 (No. 129, item 1352).
– ILO Convention for the prevention of major industrial accidents (No. 174), Geneva 1993.
– ILO Chemicals Convention (No. 170), 1999.
– IMO International Maritime Solid Bulk Cargo (IMSBC) Code, Resolution MSC.268(85), 2008.
– IMO Recommendations for the Safe Transport of Dangerous Goods and Associated Activities in Port Areas, Edition 2008.
– OECD Guidelines for chemical accident prevention, preparedness and response, 2nd Edition, 2015.

Experts, as part of the discussion, pointed out problems with the use of existing instruments in some countries. Implementation can be difficult due to the lack of:

– institutional and financial capacity,
– coordination among authorities,
– sufficient understanding of the legal instruments and how they interrelate,
– implementation and possible inconsistencies, lack of coherence in international policy-making in this area,
– lack of adequate training for workers (in warehouses and port areas and during handling and transport of hazardous materials, etc.), rescue workers and personnel working for national regional and local authorities.

A survey was conducted to analyse the global situation in the marketing of AN-based products. It included questions on lessons learned from the explosion at the port of Beirut and other accidents involving AN-based products; good risk management practices for the storage, handling and transport of AN, the legal and regulatory framework for AN risk management, and challenges and suggestions for improving AN risk management. One hundred and one responses were received from 43 countries from all UN regions and a total of over 600 pages of AN data. UNECE collated the responses, analysed them. The result was that several key areas of concern were identified:

– AN-based product classification,
– coordination between authorities,
– port management,
– safe storage and transport,
– land use and planning of storage areas,
– inspections,
– public information and security.

The explosion at the port of Beirut has prompted many governments to take action in their countries, including increased on-site inspections to ensure compliance with laws and regulations, their reviews , and awareness-raising through the media and expert dialogue. Most countries apply a number of international instruments and have national legislation on hazardous substances, including AN; relevant legislation has been notified under customs, economic, environmental, health and safety, port, safety, commercial and transport, and building and fire regulations. The analysis showed that in most countries there is no clear definition of "intermediate" or "temporary" storage; however, different rules and exemptions may apply to the storage of hazardous substances, including AN and AN-based fertilisers, depending on their properties and quantities, location and duration on site. Some respondents pointed to the need to remove hazardous substances from ports as quickly as possible and deliver them to ports just before loading. In the context of AN risk management in port areas, respondents reported that good practices include limiting the amount of AN on board a ship, having water and pumping facilities near loading docks, raising awareness of risks among port workers and carrying out preventive inspections and regular training. Some of the lessons learnt included the need for sufficient information on dangerous goods, for companies to have emergency response teams (i.e. not relying on firefighters alone), and that the various industries using AN and AN-based fertilisers have certain required technical expertise needed in emergency and crisis situations. Challenges identified included assessing the causes of detonation of AN and AN-based fertilisers in certain circumstances, managing AN residues from loading areas in ports or customs areas, building the technical capacity of staff and improving the labelling of containers containing hazardous substances. Although many countries use international standards for classification and labelling, more knowledge and understanding of the different types of AN mixtures and their ability to detonate is needed. Some respondents also stressed the importance of safety data sheets in communicating information to others and the importance of inventory and traceability systems when storing and transporting hazardous substances. There is a significant majority of countries which have made the training of workers at hazardous substance sites compulsory, and some have introduced specific training requirements at high-hazard sites. In addition, some countries have regulations requiring companies to appoint a certified dangerous goods safety advisor, DGSA. While many countries have legislation to inform the public about hazardous installations and to ensure their participation

in decisions about the location of such installations, some respondents reported that the public is not always familiar with the hazards, risks and contingency plans for sites with AN-based products.
The Seminar presented guidance developed from the causes of 23 accidents with AN-based products by the Joint Research Centre (JRC):
– Proper storage and handling practices to prevent contamination.
– Avoiding sources of ignition near fertiliser storage sites.
– Ensuring adequate preparedness measures (e.g. effective fire detection, firefighting systems and practices).
– Hazard and risk assessments and control practices should cover all AN-based products so that "off-spec" products are not overlooked.
– Raising awareness of the risks and hazards of AN among operators.
– More knowledge is needed to identify sub-standard products and the resulting risks.
– Separation of combustible materials from organic substances reduces the possibility of fire and explosion.
– Development of public living areas should be limited around sites that serve or store AN-based products.
– Local authorities and rescuers should be conscious of all AN storage sites and risks.
– Bulk storage of AN-based products should not be allowed without appropriate emergency plans.
In view of the dramatic consequences of the explosion in Beirut, the main challenges for the fertiliser industry were identified in the form of questions on areas for improvement:
– How to raise awareness and improve communication of existing guidelines to implement them effectively further down the supply chain?
– How to implement secure management systems throughout the distribution chain?
– How to manage the handling of the product during transport in ports, among others, especially with regard to maintaining high safety standards in exceptional circumstances, e.g. short-term storage in ports?
The producers' advantage in their policy recognises that the prevention of major fertiliser-related industrial accidents is crucial, and therefore places a strong emphasis on working with highly professional agents, shipowners and port operators. However, there is a wide spectrum of standards in the commercial and shipping industry. The difficult thing for the fertiliser industry to control is the maintenance of a high level of safety, regardless of where fertilisers are distributed. There are areas which are out of the producer's control throughout the product life cycle, such as unplanned interim storage during transport.
There are a number of fertiliser industry initiatives underway globally to continually improve safety and risk awareness. The Fertilizers Europe association has been running a Product Stewardship programme for several years to improve safety, security, health and environmental performance throughout the supply chain. The programme requires mandatory implementation in all member companies, and audits by an independent third party. The Association has published a number of guidelines for implementing best practice throughout the fertiliser product supply chain.
The lessons learned from the Beirut AN disaster highlighted the most relevant actions and next steps to be taken by national authorities, industry and industry organisations:
– Strengthening the implementation of legal and policy instruments.
– Raising awareness of hazardous substances and their associated hazards and risks.
– Providing resources for the classification and labelling of AN and AN mixtures.
– Improving public information on the hazards/risks associated with AN and AN mixtures.
– Ensuring that inspections have appropriate criteria and frequency.
– Application/development of traceability and monitoring systems for hazardous substances.
– Use of international notification systems and assistance mechanisms.
– Development or analysis of internal and external (off-site) emergency plans.
– Improvement of staff coordination and training.
– Sharing experiences, lessons learned, good practices with other countries, industry and industry organisations.

Areas for action for NGOs were also identified:
- Supporting efforts to strengthen the implementation of legislation and policy instruments.
- Information exchange and knowledge management, including through the development of a repository of information on international legal and policy instruments on risk management of AN and related products; industrial accident prevention, preparedness and response, implementation experience, lessons learned and good practices (UNECE).
- Update and expansion of the planned third edition of the OECD Guidelines for Chemicals, specifically the Incident Prevention, Preparedness and Response Section dedicated to port areas.
- Continued emergency preparedness involving AN and AN-based fertilisers (UNEP/OCHA JEU).
- Including industrial accidents in national disaster risk reduction strategies and action plans developed (UNDRR, UNECE).
- Strengthening the legal and compliance framework for occupational health and safety and chemical management, including in Lebanon based on a gap analysis for the area of labour law there.

4. Summary

- As part of the conclusions drawn from the discussions of the experts participating in the UN/OECD Seminar [6], it was emphasised that the fundamental requirement is to strengthen the implementation and compliance of the legal and policy instruments on the hazardous substances under consideration in order to make the accident prevention, preparedness and response guidelines effective. It was emphasised that integrating risk management for technological disasters into national, local and sectoral strategies and plans in an institutionalised manner, supported by legislation and strong governance involving all stakeholders is essential in many countries around the world. Experts raised the topic of the diversity of AN product types, in particular AN-based fertilisers, their properties and behaviour, in the context of raising awareness among supply chain participants. In the face of the disaster in question, it was stressed that a continued emphasis on accident prevention through all possible measures to ensure safety was necessary. It is good practice for industry/operators and local communities to work together to develop external preparedness and response plans. Another important element is to test these plans regularly and activate them immediately in the event of an accident. National and local authorities, including land-use planners, must take into account the results of the risk assessment in order to make informed decisions on the location of industrial installations and storage spaces in the context of cross-border transport, among other things. Supervision and enforcement are indispensable. Countries should ensure a high level of inspection to achieve effective chemical safety management. There are still areas which can be difficult to control from a producer or local authority point of view, such as intermediate/temporary storage. Such situations require deeper consideration, including the links between regulations, implications for different authorities and different approaches to risk management. Another element of safety systems is training, essential for authorities, inspectors, employees, firefighters and others. Throughout the chain, priority should be given to information about what hazardous substances are produced, transported or stored. Information activities should also be aimed at the population in the vicinity of hazardous installations (also in neighbouring countries), including details of how the surroundings may be affected by accidents and how to respond.
- For the ongoing improvement of safety standards globally, it is important to continue to exchange experiences and share knowledge. International organisations play an important role in the flow of information and knowledge exchange, identifying good practices and supporting less developed countries in their policy-making, risk management and security training.
- The troubled history of the ship which brought the AN to Beirut in 2014 could have had a very different ending if all stakeholders had coordinated their actions at different levels of implementing, meeting and inspecting safety rules to prevent the disaster which occurred six years later.

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