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CHANGES IN HANDLING AND STORAGE PROCEDURES FOR AMMONIUM NITRATE IN THE UNITED STATES AS A CONSEQUENCE OF THE EXPLOSION AT WEST FERTILIZER COMPANY (2013)

Abstract

This article presents an analysis of similarities and differences in the approach to storing ammonium nitrate in conformity with NFPA standards, which apply not only within the United States, but also in plants or storage areas owned by US corporations where the provisions of these regulations are more restrictive than those of the local law. The procedures developed by NFPA are considered to be among the best in the world in terms of the complexity of the problem analysed and the range of studies on which they had been based, as well as on post-accident analyses related to fire safety, explosion risks and, above all, the problem of protecting people from the consequences of fires or other localised hazards.

Keywords: ammonium sulphate, ammonium nitrate, storage of fertilizers, explosion hazard, ANFO self-acting formation

ZMIANY W PROCEDURACH POSTĘPOWANIA I SKŁADOWANIA SALETRY AMONOWEJ W STANACH ZJEDNOCZONYCH W KONSEKWENCJI WYBUCHU W WEST FERTILIZER COMPANY (2013)

Abstrakt

Artykuł stanowi analizę podobieństw i różnic w podejściu do przechowywania saletry amonowej według standardów NFPA, które znajdują zastosowanie nie tylko na terytorium Stanów Zjedno-

czonych, ale również w zakładach czy obszarach magazynowych należących do amerykańskich korporacji, jeżeli zapisy tych regulacji są bardziej restrykcyjne niż przepisy lokalnego prawa. Procedury opracowywane przez NFPA należą do najlepszych na świecie pod względem wielowątkowości analizowanego problemu, jak i zakresu badań, na których się opierają, a także analiz powypadkowych dotyczących danego obszaru związanego z bezpieczeństwem pożarowym, zagrożeniami wybuchowymi, a przede wszystkim problematyce ochrony ludzi przed konsekwencjami pożarów lub innych miejscowych zagrożeń.

Słowa kluczowe: saletra amonowa, azotan amonu, składowanie nawozów, zagrożenie wybuchem, samoistne powstawanie ANFO

Introduction

The city of West, Texas, was once again the victim of a massive explosion, and once more it was related to ammonium nitrate. The first Texas City disaster occurred in 1947 at the Port of Galveston Bay. It was the most tragic industrial accident in the US and one of the largest non-nuclear explosions in history anywhere in the world. The incident killed nearly 600 people and completely damaged almost 1,000 buildings [1].

Over the decades following the Texas City port disaster, changes were implemented in the law, and safety standards and norms were developed. These were intended to reduce the likelihood of such incidents occurring and, if they did, to limit their consequences. Among other things, a change was adopted to the rules for handling of the material, including storage and transport, and prohibited its storage near defined reactive materials such as fuel oil and sulphur. Refineries in the Texas City area have set up an Industrial Mutual Aid System (IMAS) as part of a plan to prevent future disasters. Other industrial areas across the country have followed suit. There are now several mutual aid systems spanning several states, using common procedures and able to provide almost unlimited resources. The first version of the NFPA 490 standard [2] – standard for the storage of ammonium nitrate was developed and adopted in 1963, based on reports from the disaster, research and earlier proposals. To date, 12 versions of the listed standard have been produced, including five in the 1960s. In 2010, all the rules for the storage, use and handling of hazardous materials in all types of buildings and facilities (excluding storage or use on the area of single and two-family residential buildings) were incorporated into NFPA 400 (Hazardous Materials Code) [3], and with this, works on subsequent versions of NFPA 490 were completed.

Additional regulations for the handling of hazardous substances in this scientific paper are contained in the 'Occupational Safety and Health Act' developed by OSHA in 1970 [4], which placed safety responsibilities on employers and required employees to comply with safety rules established at individual companies. Under this law, the standard "Hazard Communication" [5] and "Hazardous Waste

Operations and Emergency Response" (HAZWOPER) [6] was developed including many others pertaining to occupational safety. Those two OSHA standards (29 CFR 1910.1200 and 1910.120) have parallel requirements in the Department of Transportation (DOT 49 CFR) [7] and in the Environmental Protection Agency (EPA 40 CFR) [8] regulations, which ensures that all workers and workplaces are protected.

Unfortunately, all these measures did not prevent events taking place at the West Fertiliser Company in 2013. Based on a report by the U.S. Chemical Safety and Hazard Investigation Board [9] areas will be presented that had not been covered by the legislation in force at the time, but which had a key impact on how events unfolded.

Circumstances and course of the disaster

On 17.09.2013 in the West Fertilizer Company a detonation of 30 tonnes of fertiliser grade ammonium nitrate took place.

The West Fertilizer Company was a fertiliser sales and distribution facility (mostly ones that contained ammonium nitrate) in West, Texas, 80 miles south of Dallas. The company's 1,100m^2 warehouse was built of combustible materials, mainly wood. The walls that separated individual substances stored were made of wooden beams. The amount of ammonium nitrate stored in bulk at the time was estimated to be 40 to 60 tonnes, of which one separate area held about 30 tonnes.

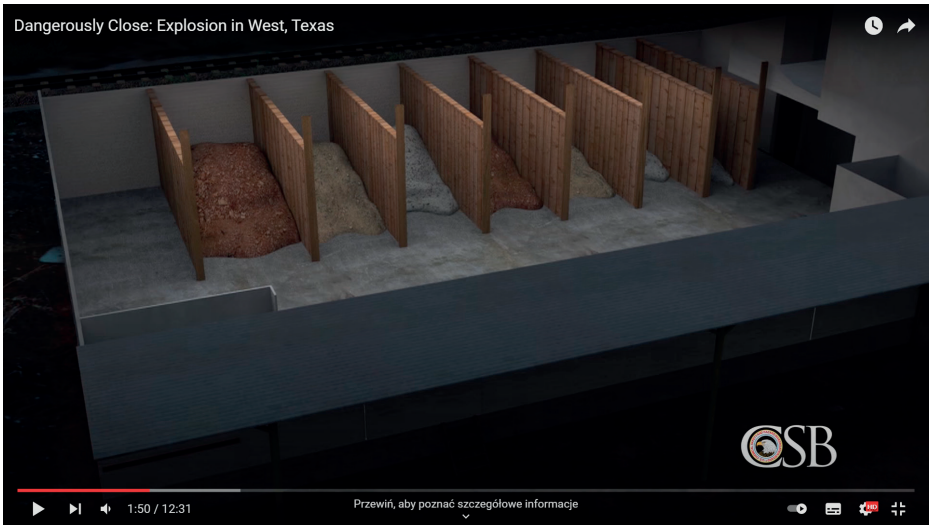

Fig. 1. Visualisation of the warehouse according to the CSB report

Source: [9]

At around 7.30 pm, a fire broke out in a storage building. The building was not equipped with a fire alarm system and so the fire was detected by a police officer during a routine patrol. Through the dispatcher, he notified the fire service of the incident. Two heavy fire engines, two light all-terrain fire engines and a water tanker from the volunteer fire service arrived on the scene.

Despite undertaking of an extinguishing action, the internal fire developed rapidly. Due to the negligible oxygen supply, incomplete combustion products (smoke and soot) began to settle on the heaps of ammonium nitrate stored in combustible wooden boxes.

At around 19.45 the nature of the fire changed. Probably due to the burning of the wooden door separating one of the ammonium nitrate piles and by the influx of fresh air through the damaged roof, the temperature inside the building began to rise rapidly. The heat was absorbed by a layer of soot on top of the ammonium nitrate pile, as a result of which rapid surface heating took place of the top layer of fertiliser, thus creating favourable conditions for an explosion.

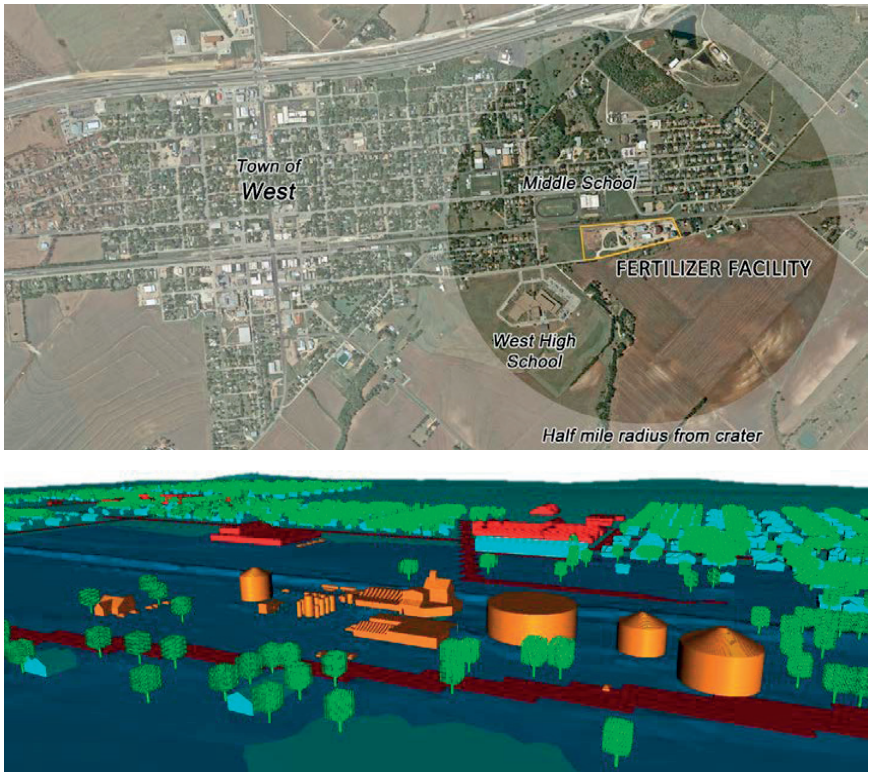

Fig. 2. The extent of effects of the explosion (visualisation based on the investigation) and a view of the fertiliser factory model

Source: [10]

From the outside, the volunteer fire brigade tried to extinguish the flames with water. Through one and a half inch hoses, water was directed to the inside of the building. The nearest external source of water for firefighting purposes was a hydrant more than 400 m away from the building.

As the fire developed, the fire chief and deputy fire chief began to discuss the appropriateness of stopping the operation and evacuating rescuers from the immediate vicinity of the building. Unfortunately, the considered action had not been taken. At 7.51 pm, twenty minutes after the fire was first reported, the detonation of approximately 30 tonnes of stored ammonium nitrate took place. This led to the deaths of 15 people, including 12 firefighters, and more than 260 people were injured.

West Fertilizer's buildings were completely destroyed. More than 150 nearby homes and businesses were damaged, some beyond repair. Across the City of West, losses were counted in the hundreds of millions of dollars.

A proper assessment of the conclusions presented by the investigators was confirmed by findings from a simulation carried out in FLACS-Blast (Figure 2).

Conclusions of the report

Although there was a lot of combustible material inside the building, the CSB was unable to determine the source of ignition or the exact location in the building from where the fire originated.

The Chemical Safety Board launched an investigation and found poor hazard awareness, proximity of the facility to nearby homes and businesses, inadequate emergency planning and limited regulatory oversight, which all led to the massive impact of the incident.

The fertilizer storage building was close to several houses, an apartment building, two schools, a city park and a nursing home.

This was due to the fact that, over the years, there were no zoning restrictions that would have prevented the construction of other facilities in the immediate vicinity of the warehouse where large quantities of hazardous materials were stored.

West Fertilizer's buildings were built on open land in 1961, but over the following years the City of West developments slowly and steadily moved towards them. Despite the potential hazards of the substances stored at West Fertilizer, zoning ordinances did not restrict the construction of houses or other buildings without assessing and delineating the extent of the potential hazard zone.

Another problem was that West Fertilizer had underestimated the risks of storing significant amounts of ammonium nitrate contained in fertilisers, especially as the buildings were made of combustible materials.

The CSB Chemical Safety Board found that this widespread lack of awareness stemmed from several factors. The main reason was that the Occupational Safety

and Health Administration OSHA did not include ammonium nitrate in its list of highly hazardous chemicals, toxins and highly reactive substances under the Process Safety Management Standard. The regulations only applied to ammonium nitrate used in the production of ammunition and explosives, such as the ANFO type. The investigation found that no federal regulations were adopted regarding the location of chemical plants in the vicinity of residential areas, schools or hospitals, and no minimum safe distances were specified depending on what substances and in what quantities could be stored. This meant that the ammonium nitrate stored at West Fertilizer was not subject to safety management requirements that could identify and mitigate the risk of explosion and its potential effects.

It was also revealed that there were more than 1,300 unregulated facilities in the United States storing fertiliser-grade ammonium nitrate. The state of Texas was found not to have any local, state regulations concerning the location of hazardous facilities near human settlements. Any plans for the zoning and siting of facilities which, based on Seveso II and III, we would consider to be low-tier or high-tier establishments, if they are included at all, apply only to the smallest territorial units - up to county level at most.

What is more, the standard for explosives and blasting agents used in mining developed by OSHA (Process Safety Management Compliance Guidelines for Explosives, 29 CFR 1910.109) [11] was not particularly well known among fertiliser companies. This was due in part to the fact that OSHA rarely cited violations of this standard at this type of facility. The CSB further found that the EPA did not include ammonium nitrate in the list of chemicals covered by its risk management programme. Given these facts, West Fertilizer was not required to conduct a risk assessment or an analysis of the potential consequences of the explosion on the surrounding buildings.

In its final report, the CSB recommended that OSHA add fertilizer-grade ammonium nitrate to the list of highly hazardous chemicals, toxic substances and highly reactive substances or update the explosives standard to ensure safer handling of explosives.

CSB also recommended that OSHA issue a decision for regional offices to inspect facilities similar to that of West Fertilizer to establish the extent to which existing requirements pertaining to ammonium nitrate are actually implemented. Where these regulations were not being followed, they were to be enforced.

The CSB also recommended that EPA revise the Risk Management Program rules by including fertilizer-grade ammonium nitrate in the list of substances under surveillance.

As indicated by the findings of the CSB investigation, regulations can be crucial to process safety and consequently to reducing the risk of explosion for many substances. As an example, West Fertilizer followed the EPA's risk management programme rules for anhydrous ammonia, which was stored in liquid form in on-site tanks. The company's employees and emergency responders showed a much

greater awareness of the risks associated with anhydrous ammonia than the hazards posed by ammonium nitrate.

The volunteer firefighters were well aware that anhydrous ammonia could potentially assume the form of a toxic cloud, capable of dispersing and covering nearby buildings. However, they did not anticipate the possibility of a fertiliser-grade ammonium nitrate explosion because they were not required to develop an external emergency plan related to the hazards posed by ammonium nitrate.

Had fertiliser-grade ammonium nitrate also been subject to specific regulations regarding its storage rules, the presumption is that a disaster of this magnitude might not have occurred. The creation of such a plan would also identify the hazards associated with all the materials (and their reactivity to each other) and perhaps help develop strategies for responding to fires of ammonium nitrate in storage facilities that are safe for rescuers and bystanders, such as allowing the building to burn down completely if this is to prevent the loss of human life. Due to lack of knowledge of the explosive hazards posed by ammonium nitrate and its mixtures (e.g. with carbon black) and a plan for dealing with a fire involving the chemical, rescuers at West simply did not have enough time to critically assess the situation before the actual explosion took place. Furthermore, the CSB's investigation revealed that there is no regulation at the federal level as to standard training requirements for handling hazardous materials in fires for volunteer firefighters.

In Texas, for example, volunteer firefighters are not trained, even at a minimal level, in the principles of handling fires involving hazardous substances.

The CSB also found that lessons learned from previous incidents involving fertiliser grade ammonium nitrate had not been effectively communicated to rescuers in other regions.

Tab. 1. Recommendations made in the U.S. Chemical Safety Board's (CSB) final report following the West Fertilizer Company incident to specific government agencies and others

No., responsible entity	Recommendation
R1-3 US Environmental Protection Agency (EPA)	Under the Emergency Planning and Community Right to Know Act (EPCRA), which is issued annually to State Emergency Response Commissions (SERCs) and Local Emergency Planning Committees (LEPCs): • Specify which chemicals need to be included in safety documents and which are exempt from this obligation • Develop guidance documents on how emergency responders should use knowledge of hazardous chemicals in the process of developing safety training, practical exercises and emergency plans, and requested increased funding for training programs for fire services to respond to fires involving fertilizer grade ammonium nitrate and other hazardous materials

No., responsible entity	Recommendation
	• Develop comprehensive requirements for LEPC annual action plans, with an emphasis on annual theoretical and practical training for local emergency response services • Develop a general document under the Environmental Protection Law (CFR: Title 40. Protection of Environment) stating that facilities that manufacture or store fertilizer are required to report them to the local emergency management centre under the Emergency Planning and Community Right-to-Know Act (EPCRA) and related regulations; once published, companies subject to the new requirements should be notified of this fact • Amend the rules in the Risk Management Programme to include ammonium nitrate used in fertilisers (FGAN) and to set a minimum threshold quantity requiring notification to the List of Controlled Substances • The produced document must include calculations for analysing the effects of an off-site explosion, which should take into account the explosive characteristics of FGAN to determine the extent of hazardous zones and overpressure levels
R4-5 U.S. Occupational Safety and Health Administration (OSHA)	Develop and issue a Regional Impact Program for OSHA standard 29 CFR 1910.109 (related to explosives and blasting agents), where a significant number of ammonium nitrate fertilizer plants similar to the West Fertilizer plant are located • Specify the minimum annual number of inspections under the Programme • Implement one of the following two regulatory changes, options (a) or (b), to address the FGAN threat: a. Add FGAN to the standard list of high-risk chemicals, toxic and reactive substances (OSHA Process Safety Management – PSM) in 29 CFR 1910.119 and establish a minimum threshold quantity. Adopt NFPA 400 as the source of recognized and generally accepted good engineering practice for FGAN equipment and processes covered by the PSM b. Revise OSHA's Explosives and Explosive Ordnance Standard, 29 CFR 1910.109, to provide assurances that the title, scope, or both of these elements clearly indicate that the standard applies to facilities that store FGAN in bulk quantities. Revise 1910.109(i), "Storage of Ammonium Nitrate," to include requirements similar to those in NFPA 400.The revision must address the following elements:

No., responsible entity	Recommendation
	i. For new buildings, the use of combustible structural materials should be banned in facilities or parts of facilities intended for the storage of FGAN and the use of combustible packaging for FGAN should be prohibited. For existing facilities, a requirement should be established to gradually replace wooden structural components and packaging with non-combustible materials over an acceptable period of time (e.g. 3-5 years from the date the standards are revised), based on feedback from the fertiliser industry ii. Requirement for automatic water extinguishing systems and fire detection systems in FGAN indoor storage facilities iii. Establishment of ventilation requirements for FGAN indoor storage facilities iv. Require all FGAN storage areas to be isolated from storage areas for combustible materials and other contaminants v. Establish minimum separation distances between FGAN storage areas and other hazardous chemicals, production processes and plant boundaries
R6 International Code Council (ICC)	In the next edition of the International Fire Code, a chapter or separate section should be developed in Chapter 50 ("Hazardous materials") or Chapter 63 ("Oxidisers, oxidising gases and oxidising cryogenic liquids") to include the following requirements for the storage and handling of ammonium nitrate (AN): a. Mandatory use of the fire alarm system and fixed fire extinguishing systems in existing buildings built of combustible materials b. Provide ventilation requirements in compliance with the International Mechanical Code to prevent accumulation of volatile products produced during decomposition of AN c. Provide fire ventilation d. Establish minimum safe separation distances between AN and combustible materials to avoid their mixing in the event of a fire e. Prohibit the use of combustible construction materials in new buildings
R7-10 Department of Homeland Security, Federal Emergency Management Agency (FEMA)	• Through a new or existing program, in collaboration with training partners, establish and implement a competitive funding mechanism for training regional, state professional and volunteer fire services in responding to fires and explosions at facilities that store ammonium nitrate for fertilizer production (FGAN)

No., responsible entity	Recommendation
	• During the review process of the programme proposal, it is important to make sure that FGAN training includes multiple delivery methods to allow for broad outreach. Training should include instructor-led courses, online and trainer courses, initial introduction and refresher training. The training course should also include both desktop and mobile capabilities to facilitate flexible delivery. The objectives of the selected training course should cover the following topics: a. The course of events related to FGAN fires and explosions, including lessons learned b. Hazards posed by other materials and chemicals stored in the vicinity of FGAN, including their reactivity with FGANs c. Development of emergency response plans for fires involving FGAN d. On-scene response and decision-making requirements for FGAN fires, including risk assessment, scene reconnaissance and situational awareness e. Information on the functioning of the National Incident Management System and the Incident Command System • Support training partners in the development and ongoing oversight of the FGAN fire training programme. In addition, evaluate the training programme to confirm that it adequately meets the objectives of the course, as well as the specific guidelines of recommendation R8 • Develop an information programme that notifies regional, state and local fire departments of available FGAN training opportunities. This programme should include the following: a. Guidance for fire service on how to identify FGAN hazards in their communities through the involvement of State Emergency Planning Commissions b. Detailed information on how to obtain FGAN training by submitting an application in response to funding opportunities c. Information on training partners and programmes that provide FGAN training
R11-R12 Texas Commission on Fire Protection (TCFP)	• Develop minimum standards for course curricula covering knowledge of hazards related to ammonium nitrate fertiliser (FGAN) for those fire service units with FGAN production facilities or storage facilities in their protected area (or in their area of operation in mutual aid to other units). In addition, develop a training programme dedicated to FGAN (analogous to those contained in R8 for FEMA)

No., responsible entity	Recommendation
	• Implement outreach to the listed fire service units, informing them of the new requirements for certification of firefighters to deal with FGAN and of training opportunities. Outreach activities should include the following: a. Guidance for the fire service on how to identify FGAN hazards in their protected area through the involvement of state and local emergency management structures b. Encourage the fire service in subordinate areas to participate in certification training in the given areas
R13-R14 State Firefighters' and Fire Marshals' Association of Texas (SFFMA)	• Develop a training programme in the subject area (in accordance with R8) for the fire service units that may operate in factories or warehouses that contain FGAN. To ensure maximum possible coverage, the certification programme should include a variety of information delivery methods, including instructor-led courses, online courses and train-the-trainer, initial and refresher training • Recommendation R14 is the same as R10 for FEMA, but applies to the SFFMA area of operation
R15-R16 Texas A&M Engineering Extension Services (TEEX)	• Recommendation R15 and R16 are the same as R10 for FEMA and R13 for SFFMA, but relate to the TEEX area of operation
R17 Texas Department of Insurance (TDI)	• For companies offering insurance to bulk FGAN stores in Texas, including excess insurers and reinsurers - guidelines should be developed and published to assist in underwriting risks and conducting annual reviews of losses incurred. The guidelines should include the following: a. Combustible construction materials for FGAN storage facilities and tanks b. Storage of combustible materials close to FGAN piles c. Adequate ventilation of internal FGAN storage areas d. Automatic sprinkler and smoke detection systems in FGAN internal warehouses e. Distances between FGAN and other hazardous materials present on site f. Potential off-site effects of a fire or explosion, including the proximity of FGAN facilities to nearby residential buildings, schools, hospitals and other community facilities.

No., responsible entity	Recommendation
	Reference should be made in the guidance to existing material from the following sources or to other equivalent guidance: a. NFPA 400, Hazardous Materials Code, Edition 2016, Section 11, "Ammonium nitrate" b. FM Global, "Property Loss Prevention Data Sheet 7-89" c. EPA, OSHA, ATF (Bureau of Alcohol, Tobacco, Firearms and Explosives); "Handbook: Safe storage, transport and distribution of solid ammonium nitrate" d. TDI, "Best practice for storage of ammonium nitrate" e. National Fire Protection Research Foundation, "Safe distances between substances in NFPA norms and standards"
R18 West Volunteer Fire Department (WVFD)	• Develop a standard for operational procedures for pre-event planning for facilities where FGAN is produced or stored
R19 El Dorado Chemical Company (EDC)	• Applies to all distributors and bulk retailers who receive FGAN manufactured by El Dorado Chemical Company (EDC) for storage or distribution purposes: a. Recommend that internal monitoring and auditing (in accordance with the latest industry standards and guidelines) be conducted at locations where FGAN is to be stored or used. Inform that such internal monitoring and auditing may be conducted as part of established product safety programmes, including ResponsibleAg[1] b. Develop a process intended to establish mutual product stewardship expectations for the customer chain. Communicate policies in the area of security to existing and new customers prior to their first delivery of FGAN. Include the following elements: i. For all FGAN sold to distributors, distributors should be encouraged to provide Safety Data Sheets and FGAN safety guidance to their customers and also to the retail outlets to which FGAN is sold or shipped ii. For all EDC wholesale retailers and non-EDC wholesale retailers who store and sell FGAN, it is recommended to check, e.g. through checklists, the following points: – Have procedures been developed for the safe handling of FGANs, and has staff training in this area been provided?

[1] ResponsibleAg is an independent non-profit organisation created to support fertiliser retailers' compliance with federal safety and environmental regulations.

No., responsible entity	Recommendation
	– Have internal emergency plans (emergency actions) been developed and should they be forwarded to local emergency management and fire brigade structures? – Are inventory reports of Level II chemicals (according to EPA classification) prepared?

Source: own study based on [9]

The method of storing FGAN fertiliser grade ammonium nitrate in buildings having a combustible structure, in open containers or piles separated by partitions, is conducive to the appearance of undesirable admixtures, as pointed out in the CSB report [9]. With no prior knowledge of this document, nor without a deeper analysis of the incident in Texas, relying on the report of the incident in France [12], laboratory tests were performed, which may be a useful supplement for the development of the documents referred to in the recommendations in Table 1. A series of articles [13–15] have been written based on the aforementioned research work carried out by the authors. They attempted to assess the explosion risk from impurities that could penetrate into stored or transported ammonium nitrate. The analysis showed that several admixtures, in different concentrations, led to intensified effects of a potential explosion or to the rapid development of a fire with much higher dynamics than in the case of uncontaminated FGAN. These include, among others, hard PVC, polystyrene, polyamide or polyurethane.

Some of these mixtures have an explosive potential in conditions that are considered to be adverse from the point of view of rescue operations. This includes both the likelihood of such a situation occurring and the strength of the explosion itself. The study found that very common polymers such as polyethylene and polypropylene definitely increase the risk of explosion and the dynamics of fire development, and they are practically invisible to users in the case of transport or storage, because they are the materials used for the bags or big bags in which they are most often packed. The same materials are used to make all types of commonly used crates or containers with a very wide range of applications both in companies and at the end user. These can also include, as in the case of the French incident, fruit boxes.

The knowledge gained from the results of the conducted research will not only help the emergency services to plan their rescue operations, deciding when and from which area to evacuate people at risk of the potential consequences of an explosion, but also to prepare and develop social campaigns aimed at the end user, such as farm owners, in order to eliminate potential risks. As can be seen from an analysis of the available scientific literature, the number of substances that can react with ammonium nitrate in a potentially hazardous manner is considerably greater

than that which exists in the public mind. The laboratory tests carried out were designed to provide preliminary test material for assessing the time available to rescuers under certain conditions between the start of a fire and the probable time of spontaneous formation of an explosive in its environment. This may contribute to improving the safety of rescuers and bystanders in cases of structure fires involving components (e.g. polyethylene, polypropylene [13], polyurethane [14], other polymers [15], organic dusts [16], soybean oil [17]) that could potentially produce an ANFO-like explosive in an uncontrolled manner. This similarity is due not only to the similar chemical structure of the organic matter in the mixture, but also to the similar decomposition reaction pathway.

Summary

The US report on the incident at the West Fertilizer Company pointed to a great many elements that have a significant influence on the development and dynamics of fire spreading in facilities that have wooden structures, and ammonium nitrate-based fertiliser stored in piles. In Polish conditions there are rather few such facilities, not only because of the disproportion in the size of the territories between the USA and Poland, but also due to the fact that very few industrial or storage facilities in our country can boast a century-long history. Two world wars significantly reduced the number of such buildings. What is of interest is the extent of the report's impact and the very specific guidelines, which address the issue (albeit without going into detail) of the need to separate ammonium nitrate from other substances. It is also surprising that ammonium nitrate as an ingredient in artificial fertiliser was not subject to supervision or registration by the administration at federal and state level. After all, this was the material used to make the explosives planted in the WTC in 1993 or in Oklahoma City two years later, where two tonnes of ammonium nitrate were used to create the bomb that destroyed the federal administration building and killed 168 people. The omission of a very large group of substances from the CSB's analysis, such as polymers, which are commonly used in numerous of human activity, could potentially be the cause of another disaster resulting from the lack of regulation in this area.

During its various life stages, ammonium nitrate often comes into direct contact with a variety of polymers. One of the most common groups of such materials are polyolefins, in particular polyethylene (PE) and polypropylene (PP), which are used, among other things, to make plastic packaging and big-bags for the storage, warehousing and transport of nitrate-based fertilisers. Despite the frequent occurrence of both substances in combination, little information is available in literature as to the fire behaviour of PP packaging and ammonium nitrate contained within it. For this reason, it was decided to carry out a series of thermal analyses using dif-

ferential scanning calorimetry (DSC) to investigate the material's behaviour under the influence of high temperatures. As it turned out in practice, the spontaneous formation of a mixture similar in composition and explosive force to ANFO was observed during a fire.

In 2021, when, as a consequence of the tragedy in Beirut (ammonium nitrate explosion in the port on 4 August 2020), a review of the progress of the implementation of recommendations made by the CSB was revisited, it was found that only 7 of the 12 of them had been implemented within 8 years of its publication [18].

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