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COMPARATIVE ANALYSIS OF THE RISK OF EXPLOSION GENERATED BY CIVIL EXPLOSIVES IN INDUSTRIAL PLACES FOR STORAGE OF EXPLOSIVE MATERIALS

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Abstract: *The fulfillment of the obligations provided by the legislation in force regarding the minimization of risks specific to industrial sites for the storage of explosive materials is a desideratum assumed by the management at the highest level. To this end, the paper aims to provide a brief description of the algorithm for assessing the risk of explosion and establishing the optimal solutions to minimize it, starting from the analysis of concrete situations in few locations from Romania.*

Keywords: explosive materials, risk analysis, safety measures, trigger factor, consequence analysis

Introduction

In this paper was performed the individual analysis of a number of 7 locations for storage of explosives in Romania, after which, based on the data collected during the individual analysis was performed comparative analysis of the risk of explosion generated by explosives for civilian use in 7 industrial sites for the storage of explosive materials, being elaborated the specific conclusions for each of the possible triggering factors analyzed, the data is being included in comparative centralized tables for each of these causal factors. In these comparative tables, the trees of events corresponding to the analyzed factor were presented and, after the risk level assessment, the results of this assessment were centralized in the form of a diagram, which provides a clearer picture of the risk level variation with the introduction of previously identified safety measures.

1. Identifying the stages of analysis of storage sites

In this part of the paper, a logical scheme for the analysis of each explosives storage site was developed, which is represented graphically in Figure 1.

In the figure below it can be seen that the first step of the analysis is to identify the location, which, in this paper, was done through checklists specific to each analyzed warehouse. After identifying the site, it is compared with the security measures characteristic of a complete site, where all the necessary security measures are implemented, followed by the effective analysis of the analyzed warehouse, by identifying possible triggers and existing security measures. After their

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identification, the risk analysis for the individual scenarios was performed, until the moment when it is verified if the analyzed site reaches the risk level of the complete site, otherwise it is necessary to introduce new security measures.

In the next stage, the consequences of the event are analyzed, based on the risk scenarios, possible effects of the explosion are being calculated, followed by the delimitation of the emergency planning areas.

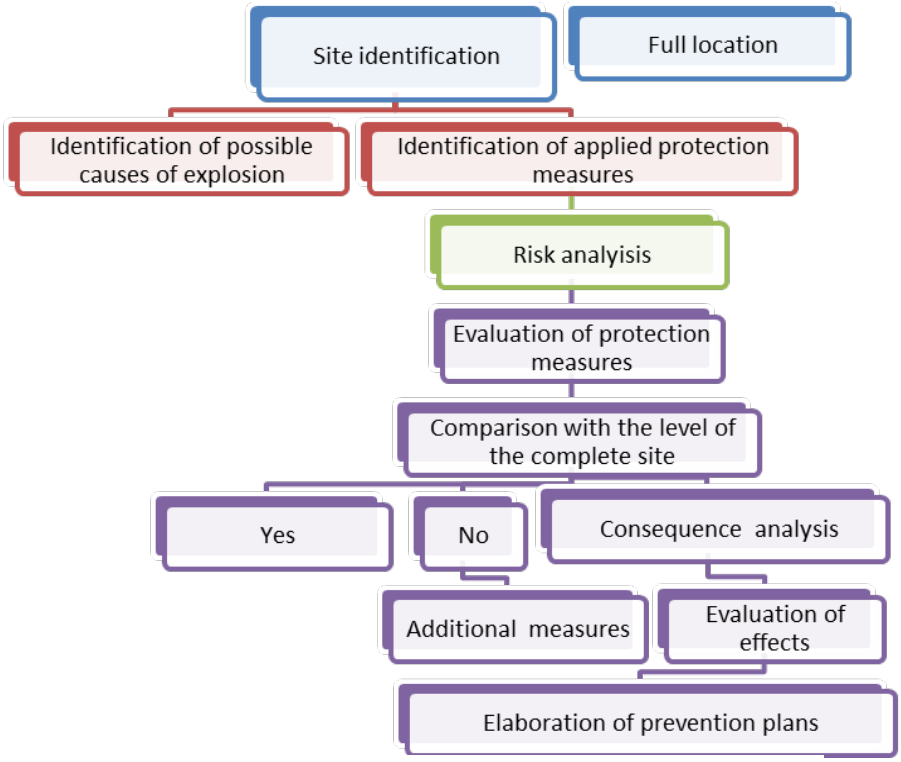


Figure 1: Logical analysis of the storage location

2. Design and development of methodology working tools. Identification of safety measures and hazardous substances for the analyzed sites. Preparation of checklists

In this part of the paper, checklists were developed to identify the technical and / or organizational security measures applied to each of the analyzed warehouses, according to the model presented in Table 1.

Table 1 Inventory table of safety measures

SAFETY MEASURES		
Symbol	**Name of the Measure**	**Description**
TECHNICAL MEASURES		
T1	*Constructive protection of the warehouse (building) - type of warehouse*	
T2	*Arrangement of separate rooms for storage of incompatible explosives*	
T3	*Protective barriers between storage rooms*	
T4	*Shock-resistant equipment*	
T5	*Racks and shelves arranged so that the impact energy is less than the ignition energy*	

T6	*Storage of explosives on shelves racks in packing boxes so as to avoid friction and / or frictional energy less than the ignition energy*	
T7	*Lightning protection*	
T8	*Earthing of electrical equipment and protection of personnel*	
T9	*Explosive distribution flow adapted to reduce storage time*	
T10	*Prevention of contact with impurities - Maintenance and cleaning of storage spaces*	
T11	*Explosion-proof encapsulation of electrical equipment*	
T12	*Disposal of sources*	
T13	*Dispersion currents with energy lower than ignition energy*	
T14	*Elimination of laser radiation sources*	
T15	*Elimination of radio sources*	
T16	*Elimination of mobile telephone radiation sources*	
T17	*Outdoor and indoor fire detectors*	
T18	*Trained operators for fire detection and operational intervention*	
T19	*Water tanks, wells water or connection of the storage to the water network, fire hydrants*	
T20	*Equipped with high pressure pumps, diesel or electric pumps*	
T21	*Equipped with sprinklers, sprinklers*	
T22	*ADR authorized vehicles, fire protected*	
T23	*Fire extinguishers*	
T24	*Barricades, fences, earth waves for protection of the deposit*	
ORGANIZATIONAL MEASURES		
O1	*Procedures for avoiding the joint storage of incompatible explosives*	
O2	*Procedures for labeling explosives by compatibility groups*	
O3	*Procedures for licensing and licensing of vehicles and drivers for the transport of dangerous goods (ADR)*	
O4	*Procedures for limiting the speed of vehicles transporting explosives inside the site*	
O5	*Procedures for clearing of vegetation inside the warehouse*	
O6	*Procedures for operating / maintenance procedures to avoid shocks caused by impact*	
O7	*Procedures for handling, loading / unloading and transport to avoid shocks caused by impact*	
O8	*Procedures for selecting equipment to reduce impact, shock absorption*	
O9	*Procedures for handling, transport and storage for prevention and reduction of contact and friction between stored explosives*	
O10	*Verification of equipment according to ATEX procedures*	
O11	*Procedures for performing explosives stability tests*	
O12	*Procedures for adapting explosives storage flow to shorten storage times*	
O13	*Quality control*	
O14	*Production control*	

O15	*Procedures for space maintenance and cleaning*	
O16	*Procedures and checks for measuring electromagnetic fields*	
O17	*Procedures for preventing laser radiation*	

Next, checklists were developed and completed, including the trigger factors and applicable safety measures according to the previously developed event sequences and event trees, which were then centralized according to the model presented in Table 2.

Table 2 Check - checklist of triggers / safety measures according to the tree and the sequence of events-Matrix of the results of the conformity assessment

Check - checklist of triggers / safety measures according to the tree and the sequence of events-Matrix of the results of the conformity assessment																
Factor code	***Trigger factor***	***Measurement code***	***Deposit A***		***Deposit B***		***Deposit C***		***Deposit D***		***Deposit E***		***Deposit F***		***Deposit G***	
			Y	***N***	***Y***	***N***	***Y***	***N***	***Y***	***N***	***Y***	***N***	***Y***	***N***	***Y***	***N***
D….																

In the next stage, checklists were developed and completed for the identification of explosives stored on the analyzed sites, according to the model presented in Table 3.

Table 3 Inventory table of stored substances

TABLE OF INVENTORY OF HAZARDOUS SUBSTANCES STORED IN THE ANALYSIS SITE									
No.	Name of the dangerous substance	No. CAS	Characteristics	Quantity	Total storage capacity	Physical condition	Storage mode	Storage / operating conditions	Location in the depot
0	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***

3. Individual analysis of storage sites based on checklists

In this part of the paper, based on the checklists presented, we proceeded to verify a number of 7 locations for storage of explosives in Romania. provided that, for security and information protection reasons, these storage sites are referred to only literally as A-G in this paper, without reference to the location of the site or any other information which by making them public may be a source of security risk for these explosives depots. For each of the analyzed sites, the checklists presented in the previous paragraph were completed, the safety measures applied to each analyzed warehouse being identified and presented.

4. Comparative analysis of the risk of explosion generated by explosives for civil use in industrial sites for the storage of explosives

The comparative analysis of the explosive deposits was carried out in compliance

with the work steps which are presented below:

- The deposit checklists have been completed, as presented in paragraph 2;
- Centralized tables specific to each previously identified trigger factor have been developed, which include all the measures provided by the accident sequences and the event trees;
- According to the data from the checklists specific to each warehouse, the summary tables have been completed with the existing measures or which, although provided by the specific event tree, are not implemented in the analyzed warehouse. In these comparative summary tables were included all the analyzed deposits, the necessary prevention measures, after which, according to the methodology and risk assessment matrix presented, the level of risk specific to the complete site was determined and for each analyzed deposit;
- When quantifying the level of risk, in order to establish clear evaluation criteria, taking into account the analysis of past events and the literature, starting from the maximum initial risk level and the frequency-severity evaluation matrix, we consider a priori that the measures prevention measures decrease the frequency for both types of organizational and technical measures, decrease the severity of the consequences for technical measures, and measures to limit the effects decrease the severity without affecting the frequency of occurrence of the event;
- After centralizing the data, specific conclusions were elaborated for each of the possible triggering factors analyzed. In these comparative tables were presented the trees of events corresponding to the analyzed factor and, after assessing the level of risk, diagrams to provide a clearer picture of the variation in the level of risk with the introduction of the necessary security measures, previously identified.

Next, for example, the comparative analysis for the trigger factor D5 - Explosion in the vicinity of the depot, according to Figure 2.1, is presented.

From the data centralized in this table you can see the following:

- The initial risk level for all locations was set at a maximum of 36 (6 on the frequency scale and 6 on the consequence scale);
- For the complete site, as the safety measures provided by the event tree are introduced, the value of the risk level decreases to the minimum value of 1, located in the field of negligible risk;
- The first measure introduced, according to the tree of events, is T24 - Barricades, fences, earth waves for the protection of the deposit, existing in all the analyzed deposits, either from the underground construction of buried type deposits and with rock cover, or from the construction storage with properly sized earth waves. After the implementation of this measure, the calculated risk level reaches the value of 16. This fact proves that, in the case of the construction of a new warehouse, its design must necessarily provide for these types of protections;
- The next measure corresponding to this trigger is given by the constructive characteristics of the warehouse and storage rooms, either by placing these storage rooms in underground warehouses, embedded in a hillside and with a layer of rock covering or the type of walls and materials used in the rooms. surface. From the summary table it can be seen that the correct implementation of this type of measure leads to the decrease of the risk level to the value of 9, close to the minimum limit of the acceptable risk range;
- Further, by applying the measure T3 - Concrete protection barriers between rooms, the level of risk decreases to the value 4, already located in the field of

negligible risk, after which, by choosing shock-resistant equipment and by storing explosives on shelves and racks corresponding to the specific storage measures, the level of risk decreases to the minimum value 1. The absence of any of these measures leads to an increase in the level of risk.

In conclusion, we have the following scenario:

An explosion produced outside the explosives depot, for various reasons, implicitly leads to the risk of explosions of the deposited materials. However, by applying the safety barriers (construction of earth waves, the existence of the rock cover, the constructive protection of the deposit, the construction of concrete partitions), the possibility of the effects of the explosion being transmitted on the explosive materials decreases continuously. If these measures are accompanied by proper storage on shelves and racks and the choice of shock-resistant work equipment, the possibility of explosive materials being initiated by the possible mechanical or thermal effects of another explosion decreases to a negligible value. it does not impose any other measures.

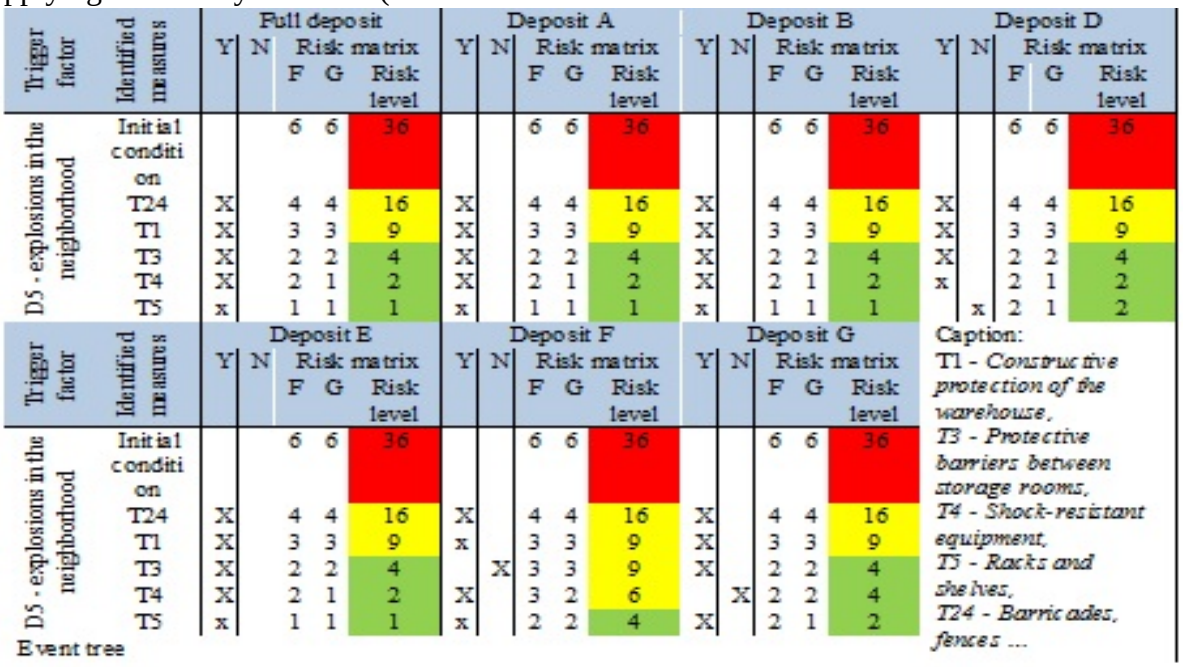


Figure 2: Explosive risk assessment for trigger factor D5

5. Conclusions

This paper describes tools and solutions to support those involved in explosion risk assessment specific to industrial sites for the storage of explosive materials and other factors interested in fulfilling the obligations under national legislation on risk minimization, as follows:

- Carrying out the individual analysis of 7 industrial sites for the storage of explosives for civil use, by identifying the possible triggering factors, of the applied safety measures, of the deposited explosives, based on the checklists;
- Development and completion of a comparative study for 7 industrial sites for the storage of explosive materials analyzed, assessment of the risk of explosion for each identified trigger factor, preparation of comparative tables and diagrams on quantifying the level of risk of explosion.

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