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# Optimizing the Degree of Integrated Security for Technical Infrastructures Intended for Storage of Explosives for Civil Use

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**Abstract**

The paper presents the results of the theoretical and practical research on developing the infrastructure for assessment of overall risk (explosion / occupational / terrorist attack) associated with unwanted events such as major accidents that can occur at explosive storehouses for civilian use. The scientific research outlined in this article was carried out within the Nucleu Project PN 16 43 02 15 – “Research on increasing safety levels at technical facilities for storage of explosives for civil use”.

*Keywords*: overall risk; technical infrastructure; major accident; explosive for civil use; terrorist attack

## 1. Introduction

Implementation of SEVESO Guidelines aims at preventing major accidents that involve dangerous substances and limiting their consequences for man and the environment. As defined in Art. (3) of the Directive, "major accident" refers to „an occurrence such as a major emission, fire, or explosion resulting from uncontrolled developments in the course of the operation of any establishment covered by this Directive, and leading to serious danger to human health or the environment, immediate or delayed, inside or outside the establishment, and involving one or more dangerous substances”.

Also, we analysed the technical requirements regarding the major risk management system, that were regulated both at European and national level through a series of European directives and transposition laws (Seveso directives, GD 804/2007, GD 79/2007, Law 59/2016, as amended and supplemented) on the control of major accident hazards involving dangerous substances as well as those specific for explosives for civil use (Directive 2014/28/EU transposed at national level by GD 197/2016, Law 126/1995 with subsequent modifications and additions regarding the regime of explosive materials).

The key element of the methodological infrastructure for assessment is represented by an integrated descriptive tool labelled "Safety Document", which aims at preventing and minimize the loss of human lives and material goods, as well as the damages caused to environmental factors in the event of major accidents.

The objective of the “Safety Document” is to demonstrate that: an accident prevention policy and a safety management system have entered into force; major-accident hazards are

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identified and the necessary measures are taken to prevent these accidents and to limit their consequences for man and environment; any installation design includes the appropriate security and reliability for construction, operation and maintenance; internal emergency plans have been drawn up, providing information to enable the development of the external emergency plan; information on land use planning decisions was provided.

In this respect, technical aspects of the management and organisational systems of a economic trader operating in the field of explosives for civil use, were analyzed in order to prevent major accidents, namely: Management and personnel; Identifying and assessing major hazards; Surveillance of the objective; Performing changes safely; Emergency planning; Supervising the capability of the safety management system; Systematic control and evaluation of the occupational health and safety management system, etc.

*In setting up scenarios regarding the occurrence of unwanted events being in the scope of SEVESO directives, such as a major accident involving dangerous substances such as explosives for civil use, it is imperative to go through the main stages of the process, namely: identification, assessment and hierarchy of risks, based on thorough knowledge, account must be taken of their maximum level of manifestation, their simultaneity and their chain development, aspects which determine that planning takes account of each individual risk, as well as their mixed or interconnected manifestations, with a view to ensuring a fast preparedness, protection and mitigation response.*

*În activitatea de configurare a scenariilor de producere a unui eveniment nedorit aflat sub incidenţa directivelor SEVESO, de tipul unui accident major care implică substanţe periculoase de tipul explozivilor de uz civil, este imperios necesară parcurgerea în mod iterativ a principalelor etape de proces, respectiv: de identificare, evaluare şi ierarhizare a riscurilor, întemeiat pe o profundă cunoaştere, trebuie să se ţină seama de nivelul maxim de manifestare al acestora, simultaneitatea şi desfăşurarea lor în lanţ, aspecte care determină ca planificarea să aibă în vedere atât fiecare risc în parte, cât şi situaţiile de manifestare combinată sau intercondiţionată, în vederea asigurării unui răspuns rapid de pregătire, protecţie şi reducere a efectelor.*

## 2. Identification and analysis of major accident hazards specific to technical facilities for the storage of explosive materials and main preventive actions

An essential component of any hazard analysis is the identification of all risk factors involved in the implementation of technical / technological systems. These factors are mainly identified with the factors behind technical dysfunctions.

Taking into account the phases and stages of putting into operation a technical / technological system, the identification and systematization of risk factors involves grouping them into the following three categories:

- *intrinsic factors*, inherent to the technical / technological system considered; not only of material nature, they are associated to the phases of designing and completing a system and essentially express the vices with which the system enters into service, at the beneficiary;
- *factors associated with exploitation and location*; these factors, also not only of material nature, are associated with all the destructive actions exerted on the technical / technological systems during their exploitation;
- *the human factor* involved in the exploitation phase, represented by all the human errors that occur during technical/technological system’s maintenance and technological exploitation activities.

The purpose of a systematic hazard analysis is to discover the sources and causes of danger, to evaluate them and establish the necessary measures to be taken in order to avoid accidents.

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Hazard analysis should be performed by using an appropriate method. The methods that can be used are: Checklist; PAAG / HAZOP; Analysis of the succession of events; Fault tree analysis; Analysis of failure effects; Dow-Index method; Zurich Hazard Analysis.

General hazards are divided into: site / process specific hazards; hazards based on incidental events (event based hazard); external hazards.

The working process is represented by team brainstorming, an inductive / deterministic type method, consisting of filling in a table with the results. Following, identification of hazards specific to explosive substances that may generate an explosion hazard is displayed, respectively:

***A. Site/process specific hazards***

1. *Loss of hazardous substances caused by mechanical overload of the equipment*

Site/process specific hazards: design error, manufacturing error, allowable temperature exceeding and degradation caused by inadequate storage conditions, etc.

2. *Loss of dangerous substances caused by uncontrolled transfer to inappropriate equipment*

Site/process specific hazards: uncontrolled/unwanted chemical reaction, failure to feed hazardous substances, etc.

3. *Loss of dangerous substances caused by a human error following an uncontrolled transfer to another equipment*

Site/process specific hazards: operating error during normal operation, operating error during maintenance/repair work, operating error during transportation of hazardous substances, etc.

4. *Loss of hazardous substances caused by the occurrence of an explosive mixture inside a storage area and ignition thereof*

Site/process specific hazards: presence of flammable/explosive substances caused by an error, occurrence of an explosive atmosphere caused by a human error, occurrence of an explosive atmosphere caused by a control system operating problem, etc.

5. *Ignition of an explosive mixture inside the storage space*

Site/process specific hazards: hot surfaces, friction, mechanical sparks; chemical reaction of self-igniting material, electrostatic discharge/equalizing currents, electrical sparks, etc.

***B. Site / process specific hazards***

*1. Damage caused by fires/toxic emissions inside storage areas*

Site / process specific hazards: insufficient fire protection, fire near a storage area, etc.

*2. Damage caused by a fire/explosion inside the storage areas*

Site/process specific hazards: short distance to other installations, insufficient/inefficient defense structures between installations, etc.

*3. Damage caused by a failure of measures for reduce explosions*

Site/process specific hazards: failure of detection systems, failure of devices for reducing explosions, etc.

*4. Damage caused by impact with a solid object*

Site/process-specific hazards: insufficient protection against impact caused by transport or adjacent objects, insufficient protection against the projectile effect caused by an external explosion, etc.

The possible effects, resulting from the analysis, are generated by the explosion hazard caused by: faulty handling, inappropriate storage and inadequate transport of highly hazardous solids.

Resulting from the analysis, the main preventive actions required are:

- the use of electrical equipment in accordance to standards provided by the in force regulations;

- compliance with working parameters and processing/handling/ loading-unloading/shipping regulations;
- regular training/authorization and retesting of operating and maintenance personnel;
- establishing a basic plan and restricted access;
- keeping emergency devices and intervention equipment in running order;
- updating the internal emergency plan, including communication protocol for current activity and for emergency situations;
- periodical checking of staff health;
- appropriate equipment and use of PPE and work equipment.

Starting from the definition of HAZARD concept, which represents the danger/likelihood of damage, general loss occurrence and/or the likelihood of a specific effect occurring in a given period or circumstances, the first step to be taken for identification of hazards is to choose an appropriate methodology, for systematic identification of hazards specific to an installation.

By way of example, if we take into account the methodology specific to checklists, performed on phases or technological processes and the guideline on "***Methodology for analysis of industrial risks involving dangerous substances***", conducted in accordance with specific requirements of *TUV Austria, TWL Seveso II / Assessment of Risks / Major Accident Effects*, then the analysis within the checklists allows for identification of process-based scenarios.

The risks of individual scenarios are related to the likelihood that an initiating event develops towards the scenario with the most serious credible consequences.

Thus, depending on the severity of the most serious credible consequences, a certain number and/or certain quality of protection barriers is necessary to ***ultimately have a tolerable/acceptable risk for each individually analyzed scenario*** (*Layer of Protection Analysis principle -LOPA-, a quantitative methodology, for assessing the necessary barriers to prevent dangerous events and to reduce risks in process units to tolerable and acceptable levels*). Existing barriers or those to be implemented to ensure an adequate level of safety will be established in accordance with the ***frequencies and consequences*** presented in the following risk matrix (Table 1):

Table 1

| Frequency | Level of consequences C1 | Level of consequences C2 | Level of consequences C3 |
|---|---|---|---|
| $10^{-2}$÷$10^{-3}$ (1/year) | | | |
| $10^{-3}$÷$10^{-4}$(1/year) | | | |
| $10^{-4}$÷$10^{-5}$ (1/year) | | | |
| $10^{-5}$÷$10^{-6}$ (1/year) | | | |
| $10^{-6}$÷$10^{-7}$ (1/year) | | | |
| **Caption:** | | | |
| | Intolerable hazard | | |
| | ALARP hazard (As low as reasonably practicable) for existing sites | | |
| | Acceptable hazard | | |
| **Consequences for population** | -One or more people on the site hospitalized for more than 24 hours.<br>-Reversible and short-term effects on health. | -A fatality or irreversible health effects for people on site.<br>-A person outside the site the hospitalized. | -More fatalities or irreversible health effects for people on site.<br>-A fatality or irreversible health effects for people outside the site |

| | | | |
|---|---|---|---|
| **Consequences for environment** | -Reversible damage on the environmental, requiring intervention by internal and external (county) forces. | -Reversible damage on the environmental, requiring intervention by external regional forces. | Massive environmental damage, possibly irreversible, requiring intervention by national / international forces. |

The significance of the areas delimited by different colours is presented in Table 2 as follows:

Table 2

| | |
|---|---|
| **Intolerable hazard** | For all scenarios that show manifestations frequencies within the red area, the protection barriers will need to be improved to reduce risk levels. |
| **ALARP hazard** | Risk reduction to the lowest reasonably practicable level: the level of risk is considered to be "tolerable" provided it has been reduced to the point where the reduction is disproportionate to the improvement achieved, costs and the fact that internationally accepted standards have been applied to control and decrease risk. The higher the level of risk, the more material and financial efforts will be needed to reduce it. Applying this reasoning to reduce the level of risk is considered to be "risk reduction to the lowest reasonably practicable level" (ALARP). |
| **Acceptable hazard** | No additional risk reduction measures are required. |

***The thick black line (the border line)*** is the line below which must be maintained all the individual scenarios analyzed for newly constructed installations.

The origin of the values underlying the risk matrix:

- $10^{-6}$ [1/year] - the value of individual unfocused risk (value often used and applied in medicine);
- $10^{-5}$ [1/year] - average statistical value for an occupational accident with fatal consequences;
- $10^{-3} \div 10^{-4}$ [1/year] - average statistical value for an occupational accident with hospitalization.

For the various scenarios that can be configured, a qualitative decision is needed to establish the effectiveness of the safety measures, according to which the accidents with consequences in columns C2 and C3 are considered major accidents in the context of the SEVESO Directives.

For the scenarios of accident type events involving explosions, the following planning areas were defined:

- *Planning area I (high mortality)* is defined as the area registering the death of approx. 50% of exposed population;

- *Planning area II (irreversible damage)* is defined as the area where the exposed population suffers severe somatic and pulmonary lesions, serious illnesses, 1st and 2nd degree burns. Light buildings suffer major damage, becoming unusable. Heavy structures may suffer minor damage;

- *Planning area III (caution area)* is defined as the distance to which the effects of the accident can be experienced and cause light, short-term illnesses or superficial, easily curable burns. In case of accidents involving explosions, light structures in the caution area may suffer minor damage.

## 3. Description of possible scenarios of major accidents at explosives storage sites

*Accidents to be prevented* - are based on operational malfunctions, which could extend to an accident because of danger sources that can not reasonably be ruled out, if their development is not stopped or limited by preventive measures. In other words, these are frequent accidents that are stopped by preventive measures and means of intervention, without degenerating into major accidents. From a practical point of view, the safety management system must take account of these accidents.

*Accidents that can, however, occur,* are the expansion of operational malfunctions, which cause a major danger, despite accident prevention measures, these generally being major accidents that are analyzed through established scenarios.

*Exceptional (catastrophic) accidents* - result from sources of danger that are not found in any of the accumulated experiences or calculation methods. Two categories of such exceptional situations can be mentioned: *natural calamities* (high amplitude earthquake which would result in the collapse of building elements, strong storms, the fall of objects from the atmosphere (e.g. collapse of an airplane) or from the cosmos (e.g. the fall of a meteorite) over the building of the explosives storage facility, with a very low probability of happening, making it virtually an unlikely event.

*Accidents that may occur in war situations and events or a terrorist attack* - these accidents, through their complexity, are treated and are usually the subject of other special plans.

*Circumstances and simulation of the accident*

An explosive storage facility has a certain authorized storage capacity expressed in ETNT. Thus an explosion accident could be initiated either by a fire accident inside or in the immediate vicinity of the deposit or the objective within the deposit, or by an explosion accident. The initiation of a fire accident inside the deposit or the objective within it, representing the initiating event of the explosion, is virtually impossible, provided that the objectives do not include internal electrical installations, do not store other flammable materials and access carrying sources of fire and open fire work are strictly forbidden.

Astfel, un accident cu explozie ar putea fi inițiat fie de un accident cu incendiu în incinta sau în imediata vecinătate a depozitului sau obiectivului din cadrul acestuia, fie de un accident cu explozie.

For modelling the consequences of the accident, the following input data should be considered: the amount of stored explosive materials, respectively the maximum storage capacity (t ETNT); explosion reaction energy (kcal / kg); explosion efficiency (%); explosion energy (ETNT). The spatial distribution of the shock wave front characteristics, expressed by overpressure (kPa) and impulse (Pa.s) relative to distance (m) is graphically illustrated in Figures 1 and 2.

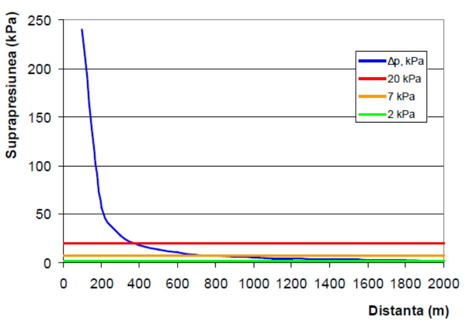


Fig.1- Overpressure variation based on distance

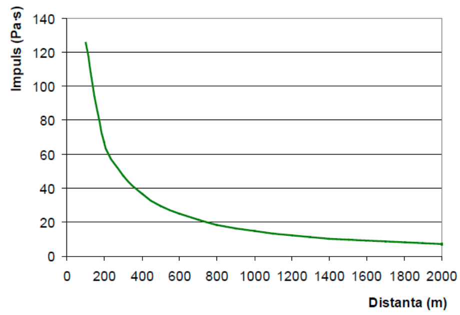


Fig.2- Impulse variation based on distance

The main accident scenarios highlighted in the paper are as follows:

- ***I. Scenario of major accident in the premises of storage spaces and II. Scenario of major accident on the storage space manoeuvring platform***, involving large amounts of explosive materials, leading to severe effects on large areas. The likelihood of an accident is extremely low, provided that the objectives do not include internal electrical installations and access on the premises carrying sources of fire is strictly forbidden. The only initiating events could be a serious human error when handling packaged explosives or an external cause such as: uncontrolled fire in the immediate vicinity of the storage place or armed attack.

***-III. Scenario for major accident at transportation inside the storage area***, which could be caused by a technical error, namely a vehicle malfunction, a handling error or a road accident. Explosive materials are transported by ADR approved vehicles, their technical condition being periodically checked. A road accident or handling errors are virtually impossible within the warehouse, provided that the speed limit is 5 km/h. Such an accident could trigger, through the Domino effect, an explosion accident at the warehouse if the vehicle is found at the loading / unloading ramp.

***-IV. Scenario for wood/stubble fire***, which could be caused by lightning bolts of a storm or by a human error. To prevent accidents caused by lightning bolts, the storage house is provided with lightning rods. As a safety measure, the tip of the canopy will not exceed the tip of the lightning rods. A human error would involve deliberate or accidental use of a fire source in the forest.

***-V. Scenario on the occurrence of a generalized explosion within the storage facility, after a terrorist armed attack***; it can be appreciated that this type of event is virtually impossible given the security measures taken by this type of technical infrastructures.

The following is an example of risk assessment for the storage area.

**Risk evaluation:**

The specific risk assessment for these scenarios is shown in Table 3.

Table 3

| Scenario | Simulated hazard | Probability of occurrence | Consequences | Risk quantification |
|---|---|---|---|---|
| **I. Inside the storage facility** | | | | |
| **Reasonable scenarios:** | | | | |
| ***I.1.1 Building X – detonator storage***<br>- handling or storage error, dropping boxes of detonators or boxes dropping from the stack;<br>- explosion of a box;<br>- explosion of the entire amount stored caused by the shock wave of the explosion or fire. | Explosion overpressure | $10^{-6}$ | C2 | **Acceptable risk** |
| ***I.1.2 Building Y - explosive storage:***<br>- handling or storage error, dropping boxes of explosive materials or boxes dropping from the stack;<br>- explosion of a box;<br>- explosion of the entire amount stored caused by the shock wave of the explosion or fire;<br>- individual explosion of a stockroom. | Explosion overpressure | $10^{-7}$ | C3 | **Acceptable risk** |
| ***I.1.3. Fire in the generator room (if there*** | Explosion overpressure | $10^{-6}$ | C2 | **Acceptable risk** |

| | | | | |
|---|---|---|---|---|
| ***is such a situation) and fire expansion towards the detonator stockroom:***<br>-explosion of detonators deposited in Building X caused by rising temperature. | | | | |
| ***I.1.4.Large scale fire of vegetation outside the storage facility:***<br>- fire spreading to the inside vegetation;<br>- explosion of explosive materials within the storage facility caused by temperature rise (time-lag);<br>- the explosion of a stockroom or more, depending on the response to the emergency situation. | Explosion overpressure | $10^{-7}$ | C3 | **Acceptable risk** |
| **Scenarios having the most severe consequences:** | | | | |
| ***I.2.1. Damage to construction elements and their falling over the stored material caused by a high amplitude earthquake.***<br>- Explosion and fire leading to the explosion of the entire explosive material stored in the storage facilities (successive explosions at short intervals). | Explosion overpressure | $10^{-7}$ | C3 | **Acceptable risk** |

**Assessment of the magnitude and severity of the consequences of identified major accidents:**

The assessment of the magnitude and severity of the consequences is shown in Tables 4, 5 and 6.

Table 4

**A.Scenarii rezonabile:**

| **Scenario** | **Simulated hazard** | **Dangerous area (circular area expressed by radius R)** | | |
|---|---|---|---|---|
| | | **Area I Mortality (m)** | **Area II Irreversible damages (m)** | **Area III Reversible damages (m)** |
| | | **Destruction of buildings** | | |
| | | **Total and powerful destruction of buildings** | **Moderate destruction of buildings** | **Insignificant destruction of buildings Broken windows** |
| | | **Impact on health** | | |
| | | **Very severe and severe injuries** | **Moderate injuries** | **Light injuries** |
| ***I.1.1 Building X – detonator storage***<br>- handling or storage error, dropping boxes | Explosion overpressure | $R_{11} < R_{21}$ (measured using IMESAFR v2 ) | $R_{21} < R_{31}$ (measured using IMESAFR v2) | $R_{31}$ (measured using IMESAFR v2) |

| | | | | |
|---|---|---|---|---|
| of detonators or boxes dropping from the stack;<br>- explosion of a box;<br>- explosion of the entire amount stored caused by the shock wave of the explosion or fire. | | | | |
| ***I.1.2 Building Y - explosive storage:***<br>- handling or storage error, dropping boxes of explosive materials or boxes dropping from the stack;<br>- explosion of a box;<br>- explosion of the entire amount stored caused by the shock wave of the explosion or fire;<br>- individual explosion of a stockroom. | Explosion overpressure | $R_{12} < R_{22}$ (measured using IMESAFR v2) | $R_{22} < R_{32}$ (measured using IMESAFR v2) | $R_{32}$ (measured using IMESAFR v2) |
| ***I.1.3. Fire in the generator room (if there is such a situation) and fire expansion towards the detonator stockroom:***<br>-explosion of detonators deposited in Building X caused by rising temperature. | Explosion overpressure | $R_{13} < R_{23}$ (measured using IMESAFR v2) | $R_{23} < R_{33}$ (measured using IMESAFR v2) | $R_{33}$ (measured using IMESAFR v2) |
| ***I.1.4.Large scale fire of vegetation outside the storage facility:***<br>- fire spreading to the inside vegetation;<br>- explosion of explosive materials within the storage facility caused by temperature rise (time-lag);<br>- the explosion of a stockroom or more, depending on the response to the emergency situation. | Explosion overpressure | $R_{14} < R_{24}$ (measured using IMESAFR v2) | $R_{24} < R_{34}$ (measured using IMESAFR v2) | $R_{34}$ (measured using IMESAFR v2) |
| **Overpressure value** | | 0.45 bar | 0.07 bar | 0.03 bar |
| **On site objectives** | | On site, the following objectives can be found:<br>- other storage facilities;<br>- security lodge;<br>- Access gate area and perimeter fence;<br>- Water tank. | On site, the following objectives can be found:<br>- Office buildings, storage house for PSI materials;<br>- Water tank;<br>Outside the site, the following objectives can be found:<br>- access road to the warehouse;<br>- vegetation and land belonging to the area in the vicinity of | Outside the site, the following objectives can be found:<br>- access road to the warehouse;<br>- vegetation and land belonging to the area in the vicinity of storage facility. |

| | | | |
|---|---|---|---|
| | | storage facility. | |
| **Exposed personnel and affected population** | Number of exposed workers | Number of exposed workers + number of people who may be affected (measured using IMESAFR v2 / DIRE Version 1.0) | Number of people who may be affected (measured using IMESAFR v2 / DIRE Version 1.0) |

## B. Scenarios having the most severe consequences

Table 16

| **Scenario** | **Simulated hazard** | **Dangerous area (circular area expressed by radius R)** | | |
|---|---|---|---|---|
| | | **Area I Mortality (m)** | **Area II Irreversible damages (m)** | **Area III Reversible damages (m)** |
| | | **Destruction of buildings** | | |
| | | **Total and powerful destruction of buildings** | **Total and powerful destruction of buildings** | **Total and powerful destruction of buildings** |
| | | **Impact on health** | | |
| | | **Very severe and severe injuries** | **Very severe and severe injuries** | **Very severe and severe injuries** |
| ***I.2.1. Damage to construction elements and their falling over the stored material caused by a high amplitude earthquake.*** - Explosion and fire leading to the explosion of the entire explosive material stored in the storage facilities (successive explosions at short intervals). | Explosion overpressure | Ellipsoidal area $R_{11} < R_{21}$ Distance between centres (m) (measured using IMESAFR v2) | Ellipsoidal area $R_{21} < R_{31}$ Distance between centres (m) (measured using IMESAFR v2) | Ellipsoidal area $R_{31}$ Distance between centres (m) (measured using IMESAFR v2) |
| **Overpressure value** | | 0.45 bar | 0.07 bar | 0.03 bar |
| **On site objectives** | | On site, the following objectives can be found:<br>- other storage facilities;<br>- security lodge;<br>- Access gate area and perimeter fence;<br>- Water tank.<br>Outside the site, the following objectives can be found:<br>- access road to the warehouse;<br>- vegetation and land belonging to the area in the vicinity of storage facility. | Outside the site, the following objectives can be found:<br>- access road to the warehouse;<br>- vegetation and land belonging to the area in the vicinity of storage facility. | Outside the site, the following objectives can be found:<br>- access road to the warehouse;<br>- vegetation and land belonging to the area in the vicinity of storage facility. |
| **Exposed personnel and affected population** | | Number of exposed workers | Number of exposed workers + number of people who may be affected (measured using IMESAFR v2 / DIRE Version 1.0) | Number of people who may be affected (measured using IMESAFR v2 / DIRE Version 1.0) |

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## 4. Computerized assessment of global risk specific to explosives warehouses (explosion risk/ occupational risk/ terrorist attack risk

Utilizing the complete software package that's specialized in global risk assessment domain type **IMESAFR v2.0 Bundle and DIRE v1.0** within civil use explosives warehouses which was purchased in phase 2 2016/2017 of Project PN 16 43 02 15, ensures the necessary premises in elaborating in fair and high accuracy conditions of "Security Document" to these types of technical infrastructures and also ensures a quantification of the damage degree onto work systems and adjacent area which are located in near vicinity. (figure no. 3)

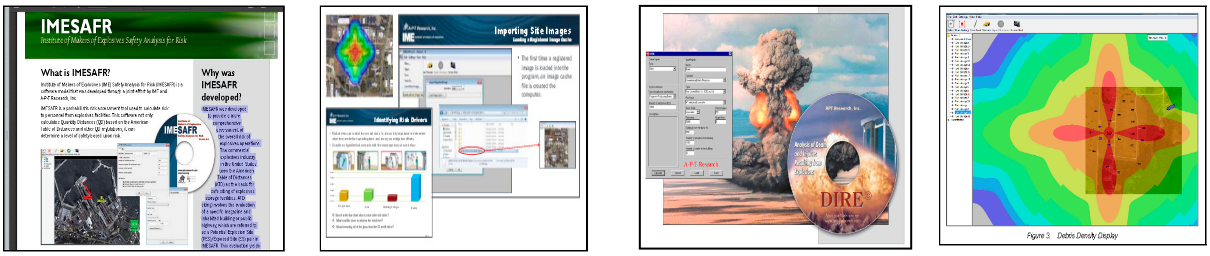


Fig.3- Complete package IMESAFR v2.0 Bundle and DIRE v1.0 Software

**<u>IMESAFR v2.0 Bundle and DIRE v1.0</u>**

IMESAFR v2.0 Bundle is a software specialized in probabilistic assessment of risk for explosive storage units staff, which calculates QD (Quantity Distances) – safe distances to explosives warehouses and can determinate the safety level based on the evaluated and estimated risk.

DIRE v1.0 is a software specialized in automatic analyse for risk assessment and in likely vulnerabilities, following of potential terrorism or other explosion incidents.

For highlighting the way of using these two software (IMESAFR version 2.0 and DIRE version 1.0), in the following we have a few examples of results obtained by the specific scenarios simulations which were configured at the afferent establishment of INSEMEX Explosive Shooting Range within which an underground explosive warehouse exists (figures no. 4,5 and 6).

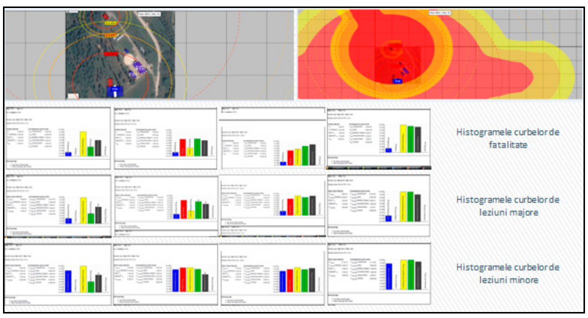


Fig.4.- IMESAFR version 2.0
Risk curves and outline map in the case of explosive materials warehouses, as well the histograms of affected areas on human components and structures.

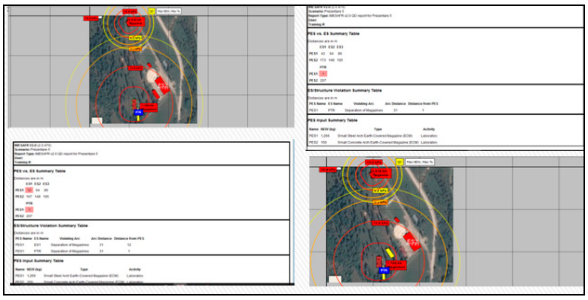

Fig.5.- IMESAFR version 2.0
Determination of the safety distance through tracing the QD (Quantity Distance) curve.

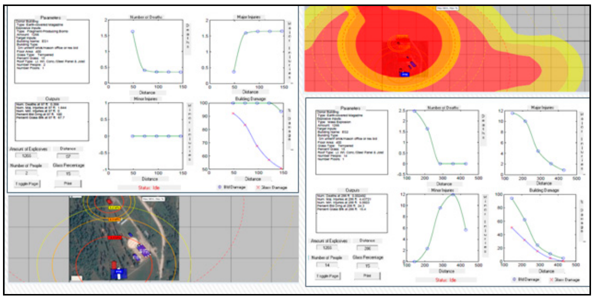

Fig.6.- DIRE version 1.0
Bomb explosion with fragment projecting and mass explosion.

## 6. Conclusions

**6.1.-** Globally, un unwanted event taking the form of an accident in a warehouse of explosive materials can happen in the following circumstances: military, air or terrestrial strike; terrorist attack; a serious human error; an accident in the vicinity of the warehouse.

**6.2.-** The consequences of an event such as an accident involving an explosion comes from the following factors: overpressure of wave shock front (the mechanic effect of explosion), which cause destructions of the buildings and human casualties; the thermal effect of explosion, afferent to fire ball model which initiates fires to the immediate surroundings and cause the deaths of exposed persons: by generating gaseous pollutants (nitrogen oxides) as chemical reaction.

**6.3.-** Utilising the complete software package specialised in global risk evaluation domain of the type IMESAFR v2.0 and DIRE v1.0 to explosives of civil use warehouses which was purchased during the Project PN 16 43 02 15/2016-2017 - Program NUCLEU, ensures the necessary premises for elaborating, in objective and high accuracy conditions, of "*Security Document*" to these types of technic infrastructures and the degree to which it will affect the work systems and the adjacent area of their vicinity.

**6.4.-** The main accident scenarios which were analysed during the trial are the following: ***I.*** Major accident scenario inside some storage facilities and ***II.*** Major accident scenario on the afferent platform of storage facilities; ***III.*** Major accident scenario to means of transportation located inside the storage facilities; ***IV.*** Scenario concerning forest fire. ***V.*** Scenario concerning a general explosion in explosive materials storage facility, as a result of a terrorist shooting.

**6.5.-** For highlighting the way of usage of the two specialised software (IMESAFR version 2.0 and DIRE version 1.0), in the paper are presented some examples of results obtained by the simulation of specific scenarios which were configured at INSEMEX testing facility for civil use explosives, within which there is an underground explosives warehouse.

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