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ANALYSIS OF THE LOCATION OF THE EXPLOSION ZONES UNDER MILITARY AIRPORT

This article is dedicated to logistics problems in the Armed Forces of the Republic of Poland. Considering Polish membership in NATO and the requirements resulting from that fact, the authors of this article focused on one of the most important issues of contemporary military logistics system, i.e. warehouse facilities. Since there are three categories of possible scenario for current military actions (the country's defences, stabilization missions and internal security), they paid particular attention to the aspect of location of warehouses where military hazardous explosive materials are stored. Pursuant to legal requirements they are listed to the ARD classification. Based on regulations being in force in Poland, the authors presented the importance of designating the security zones for a model embanked object situated in the neighbourhood of civil buildings. For this object, impact zones, including changes in landform feature, were presented.

Keywords: explosion zones, safety zones, hazardous materials

1. INTRODUCTION

Logistics plays a crucial role in both, civil and military actions. When Poland accessed NATO structures in 1999, particular emphasis was placed on optimization of the Armed Forces of the Republic of Poland (abbreviated AFRP) logistic system, in its most comprehensive sense. According to Szymański [19], nowadays logistics becomes a supranational issue, which means that logistic system of AFRP has to be

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ready to cooperate with other armies of the Alliance. It is caused, among others, by [2, 3, 5–9, 12, 19]:

- diversification of places of stationing of troops from particular NATO member states (different countries on different continents),
- diversification of missions of NATO troops location,
- expeditionary character of military actions and their diversity,
- diversification of troops armament of particular NATO member states,
- necessity to reduce costs of AFRP functioning,
- raising the standard of technical conditions of AFRP functioning.

Considering the field of logistics operations [13], other tasks of AFRP may be pointed out and they are related to:

- processing an order,
- stock management,
- warehouse,
- transportation,
- packaging.

In the case of many military operations, a particular attention is focused on the logistics of hazardous materials, which included [10, 24]:

- organization of transportations,
- labelling of materials,
- storage of materials.

Due to the specificity of hazardous materials used by the army [1, 11], the warehouse is of crucial importance and it should fulfil specific requirements.

2. STORAGE OF HAZARDOUS EXPLOSIVES

2.1. Definition of hazardous explosives

Hazardous materials are defined as substances or preparations which, due to their chemical, physical or biological properties may cause death, health disorder, injury, damage or material losses, if not properly handled [24]. According to the ADR Agreement [4], they are divided into 9 classes (Fig. 1).

In the field of defence, class 1, i.e. explosives, is of crucial importance. From the chemical and physical perspective, the explosive material is an isolated chemical compound or a mixture of chemical compounds (also found in an object) which is capable in specific conditions of producing sudden and fierce chemical reaction of an exothermal character [18]. Such a chemical reaction caused by various external stimuli (mechanical, for instance: explosion of another material, touch), by supplying light or current, by heating up, or by contact with another chemical substance, is

accompanied by emitting a large quantity of gaseous products in a form of so-called explosion.

Classification	
Hazardous materials	Class 1 Explosives
	Class 2 Gases
	Class 3 Flammable liquids
	Class 4.1 Flammable solids, self-reactive substances and desensitized explosives
	Class 4.2 Substances liable to spontaneous combustion
	Class 4.3 Substances which, in contact with water, emit flammable gases
	Class 5.1 Oxidizing substances
	Class 5.2 Organic peroxides
	Class 6.1 Toxic substances
	Class 6.2 Infectious substances
	Class 7 Radioactive materials
	Class 8 Corrosive substances
	Class 9 Miscellaneous dangerous substances and articles

Fig. 1. Classification of hazardous materials according to the ADR Agreement [4]

Within the frames of class 1, we may distinguish the following divisions [4]:

- 1.1: Substances and articles which have a mass explosion hazard.
- 1.2: Substances and articles which have a projection hazard but not a mass explosion hazard.
- 1.3: Substances and articles which have a fire hazard and either a minor blast hazard or a minor projection hazard of both, but not a mass explosion hazard.

- 1.4: Substance and articles which present a slight risk of explosion, in the event of ignition or initiation during carriage.
- 1.5: Very insensitive substances having a mass explosion hazard which are so insensitive that there is very little probability of initiation or of transition from burning to detonation under normal conditions of carriage.
- 1.6: Extremely insensitive articles which do not have a mass explosion hazard.

Class 1 covers, for instance, pyrotechnic substances designated to produce, among others, light or sound effects. In the case of substances used by AFRP, this class covers, among others, aerial bombs, air-to-air missiles, air-to-surface missiles, and anti-ship missiles.

2.2. Rules for proper storage of hazardous explosives

Hazardous explosives may be stored only in a warehouse facility. Warehouse facility is a storage space and a building where explosives produced or designated to trade, armament, ammunition and other articles for army or police, as well as explosives from clearance the land, are stored [15].

In the case of storing the military hazardous explosives, the type of bomb or missile should be considered to provide strict quality and quantity control and to provide special occupational health and safety precautions resulting from workplace regulations and from technical instructions for storing hazardous explosives. The quantity of dangerous substances stored in a given warehouse should not exceed prescribed limits.

Apart from that, the warehouse facility should be protected against theft and access of unauthorized persons. To provide that, every person entering this facility should be registered. Moreover, facility's door should be equipped with devices enabling to check if anybody tried to open it without authorization (for instance: door plastic security seals, door counters, electronic signal devices, etc.). Some fundamental rules for proper storage of dangerous substances are as follows [15]:

- Hazardous explosives should be protected properly against stimuli which would cause their explosion, ignition or loss of their specific technical parameters.
- Packages or containers with articles should be placed in such a way that they would not move, fall, deform accidentally under excessive weight. Stability of stored articles and their proper ventilation during storage should be provided.
- Boards or wallcharts with information on explosives and ammunition classes, divisions, and compatibility groups; on permissible quantities of articles and on permissible number of working staff being at the same time in the warehouse should be placed inside the storage space.
- Packages for storing military hazardous explosives should be closed tightly and sealed with a metal or indelible seal.

- To guarantee security, it is forbidden to leave or place packages with hazardous substances or articles along service walkways and in control passages.
- Storage of loose hazardous explosives is forbidden.

2.3. Requirements for buildings designed for storing hazardous explosives

Current legal regulations [14–17, 20–23] give clear requirements for buildings serving as warehouse facilities for hazardous explosives. Warehouses, where explosives are stored, should fulfil requirements as to human life, health, property and environment protection. Those requirements may be divided into four fundamental groups (Fig. 2). As to the first requirement (proper location of the warehouse facility), it is necessary to:

- locate objects only in detached buildings,
- keep safe distance from other objects in its vicinity, beyond the administrative and barracks as well as housing places,
- provide technical security in a form of embankment around the object or using natural barriers such as a thick forest or hills to improve security,
- precisely determine security zones (impact zones) to reduce to minimum the threat posed by explosives with respect to the type and quantity of stored substances.

Apart from that, there should not be any factors which may pose a risk of explosion, burning or loss of special technical parameters of the stored substances or articles in the vicinity of such an object. As to design of the warehouse facility, it should:

- be a single-storey building;
- possess light, flat roof;
- be constructed of non-flammable materials of demanded class of fire resistance;
- if it has, for instance, linear drainage system, its elements should be made of non-sparking metals, such as brass.

Requirements for storing hazardous explosives	
I. Suitable warehouse location	II. Proper design of the warehouse
III. Proper equipment and protection	IV. Proper operation

Fig. 2. Classification of hazardous substances according to ADR Agreement [15]

Last, but not least, requirement for storing hazardous explosives concerns the service personnel. Therefore, specified procedures should be observed, for instance:

- before entering the storage premises, servicing personnel should hand over all devices and objects that may cause sparking (for instance, mobile phones, matches, lighters);
- before entering the storage premises, servicing personnel should remove any static electricity from their clothes by touching earthing plate placed in front of the entrance to the warehouse facility;
- use only non-sparking tools while doing any servicing works.

3. CALCULATIONS OF SECURITY ZONE FOR HAZARDOUS EXPLOSIVES WAREHOUSE FACILITY WITH EMBANKMENT

3.1. Assumption

To provide safe storage of hazardous explosives and to avoid significant damages being a result of uncontrolled explosion of hazardous explosives, calculations of security zones, also referred as impact zones, were made. Those zones represent the possible range of damage and its intensity being dependent on the shock wave pressure. To determine security zones, calculations are made pursuant to the Regulation of the Minister of Economy of 27 October 2010 [15] on Storage Space and Rooms and Structures for Storing Explosives, Weapon, Ammunition and Police and Military Products.

Calculation of maximum quantity of hazardous explosives, expressed in equivalent mass of hexogen charge (G), which may be stored in a given building were made with an assumption that the determined impact zones for particular sizes of shock wave P_f do not cause hazard to existing buildings outside the close area (on the open area). Apart from that:

- In the warehouse facility military hazardous explosives included in class 1 and the following divisions: 1.1, 1.2, 1.3, and 1.4 will be stored and handled.
- Maximum size of building impact zones not causing hazard to the existing objects in the closed area and outside this area were determined on the basis of the Regulation [15].
- For the assumed size and impact zones, the maximum quantities of equivalent mass of hexogen charge (G) expressed in kg of model hexogen of stored charge able to generate the explosion of shock wave (P_f) were calculated for the assumed divisions of hazardous explosives.

3.2. Calculation algorithm

In the example under consideration, the following algorithm of calculation was assumed based on the formulae according to the Regulation of Ministry of Economy of 27 October 2010 [15]:

- Determination of the zone „1” of $P_{f1} = 1$ kPa, based on the site location plan, by determining the radius of maximum safety distance.
- Determination of the value of the equivalent mass of hexogen charge (G) for a distance from 80 to 500 m. It determines the maximum quantity of hazardous explosives to be stored in a given warehouse facility. For the example under consideration:

$$G = 0.63 \sqrt[0.63]{\frac{L_d - 27.1}{3.693 \cdot P_f^{-1}}} = 0.63 \sqrt[0.63]{\frac{500 - 27.1}{3.693 \cdot 1^{-1}}} \approx 2213 \text{ kg} \quad (1)$$

where: G is equivalent mass of hexogen relative to the model hexogen of the stored charge able to generate a shock wave at explosion [kg], L_d is minimum permissible distance from the base object with embankment [m] and P_f is overpressure of the shock wave [kPa].

Tab. 1 contains examples the net explosive weight of several common explosives, where $G = 2213$ kg.

Determination of security zones for basic objects for the following values of shock wave [15]: $P_{f1} = 3$ kPa, $P_{f2} = 5$ kPa, $P_{f3} = 35$ kPa, $P_{f4} = 60$ kPa and $P_{f5} = 80$ kPa. For instance, for the case under consideration, for $P_{f1} = 3$ kPa the minimum permissible distance from the basis object with embankment is 184.73 m, and for $P_{f2} = 5$ kPa this value is reduced to 122 m.

Table 1

Net explosive weight of several common explosives ($G = 2213$ kg)

No.	Explosives	Explosion heat Q [kJ/kg]	Volume of the evolved gas V [dm ³ /kg]	Net explosive weight M [kg]
1	Gunpowder	3198	250	5255
2	Nitrotoluene (TNT)	4184	700	2745
3	Nitroglycerine (NG)	6276	716	2216

Example of a location of the warehouse facility designated to store hazardous explosives with marked impact zones is shown in Figure 3. As it can be noticed, the

shape of impact zones changes depending on occurred obstacles. Moreover, some impact zones coincide with inhabited areas – farm buildings.

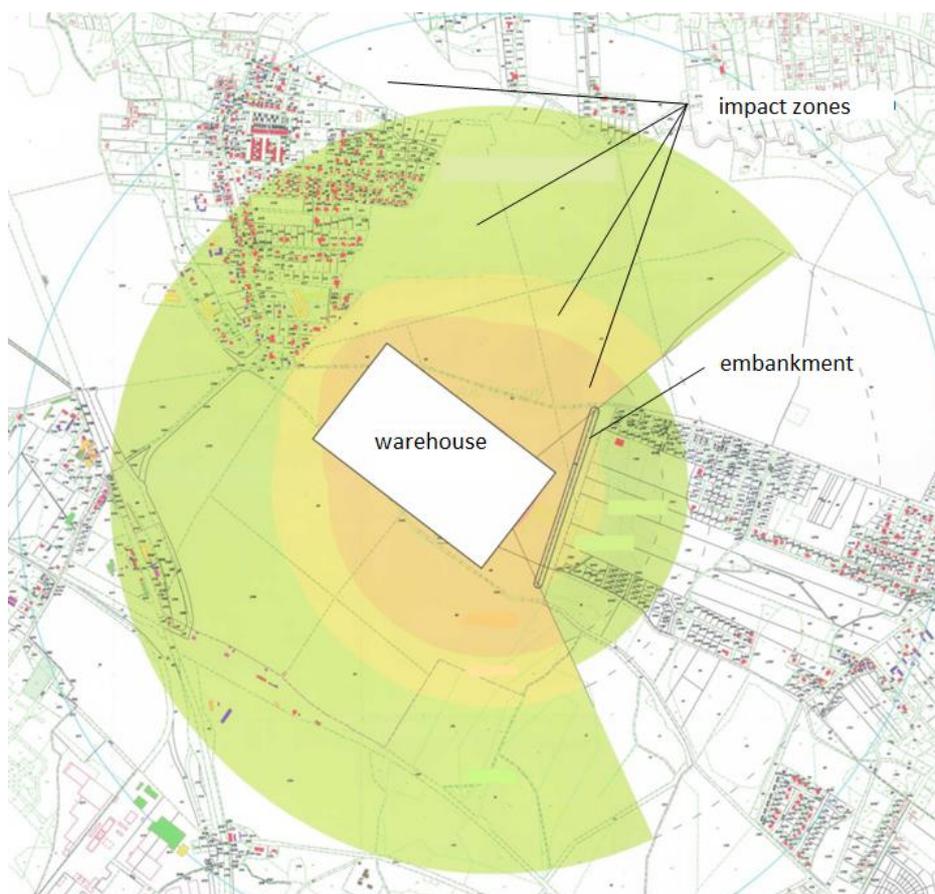


Fig. 3. Location of warehouse facility for hazardous explosives

4. CONCLUSIONS

Due to their physical and chemical properties, hazardous explosives demand specific operations in terms of logistics, in its broadest sense. In the case of military explosives, either in peacetime or during missions, location of warehouse facilities is of a great significance. According to the authors of this paper, analysis of warehouse facility location is a very important element at the stage of designing such warehouse facility where hazardous explosives would be stored, since if such facility is built, for example, in the vicinity of inhabited buildings, it may generate protests or considera-

ble financial outlays as a result of damages for limitation of property usage (ban on building) as well as financial outlays for erecting such a warehouse. Increase of building costs may be a result of the necessity to make additional earth embankments in front of inhabited buildings.

To conclude, designing security zones, observation of occupational health and safety regulations, properly designed and built warehouse facilities as well as systematic inspections of building structures (in accordance with the building regulations), where warehouses for explosives are located, allow to minimize the hazard and use safely the warehouses for operational means.

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ANALIZA LOKALIZACJI STREF WYBUCHU W OBSZARZE LOTNISKA WOJSKOWEGO

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