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Modelling and evaluation of accident in industrial company with usage of multi – criteria analysis

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Modelování a hodnocení mimořádné události v průmyslovém podniku s využitím multikriteriální analýzy

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Abstract

The submitted paper applies theoretical approaches for the modelling of the extraordinary events such as the fire and explosion's creation to a practical case study in the industrial area where it models the potential release of the dangerous chemical substances from a device. For targets of this article the release of the gas from the pipeline is modelled, and there are assessed the consequences after the release on the surrounding buildings where are the employees of the company, by means of the multi – criteria analysis.

Keywords: multi – criteria analysis, gas, threat zone

Abstrakt

Předkládaný příspěvek aplikuje teoretické přístupy k modelování mimořádných událostí jako je vznik požáru a výbuchu do praktické případové studie v průmyslovém areálu, kdy modeluje potenciální únik nebezpečných látek ze zařízení. Pro účely článku je simulován únik plynu z potrubí, kde jsou hodnoceny následky po tomto úniku na okolní budovy, kde se vyskytují zaměstnanci podniku, pomocí multi – kriteriální analýzy.

Klíčová slova: multikriteriální analýza, plyn, zóna ohrožení

1. Introduction

In compliance with a development of technological and technical devices also an amount of dangerous chemical substances and chemical agents increases. These are used in technologies, warehouses, in a transport between the industrial companies. Due to the fact that a lot of accidents from a historical point of view happened, many enterprises have an interest to increase a level of safety within a handling, storage and transport of the chemical substances .

Generally due to consequences of major accidents caused by failures in technological devices, pipelines, and warehouses, it is necessary and important to manage all safety risks which can have a serious impact and caused the following [5]:

- humans losses,
- poverty losses,
- breakdown of technological process,
- breakdown of the production,
- company image disparagement (good will).

As per the national legislations, the employers have to prevent the risks and remove them or minimize the residual risks [4].

2. Objectives

The goal of the paper is to assess the real case study in the industrial company connected with the storage and the transport of the chemical substances and the chemical agents. In the company there is considered and chosen a critical area with a big movement of internal end external employees.

As the chosen area, the article focuses on the gases transport in the production cycle. The company products by own technologies, uses, stores, transports the waste metallurgical gases like blast furnace gas, coking gas, mixed gas and the technical gases like acetylene, oxygen and nitrogen.

3. Considered methods in risk management

The evaluation of the risk which results from the extraordinary accident is calculated by means of multi – criteria analysis. This analysis can be divided into particular steps. The procedure of it is described below:

- Determination of coefficients of particular factors which are evaluated within the accident assessment. These coefficients are determined for the whole company by the team where the experts, the risk manager, management, the representative of insurance company participate. Also databases from the insurance companies could be used. The experts do not have to evaluate all factors, only these which are under their responsibilities and competencies.
- Accident’s threats identification. In the company approximately 4 – 10 technological parts are chosen. It means i.e. gas storage, the boosters pump stations, the gas pipelines, the gas holder.
- The assessment of particular technological devices with a higher probability of risk.
- Evaluation of the factors by the chosen technological device carried out by the team of the experts. This step results from the modelling of the extraordinary accident.
- The result is the evaluation of the risks in particular parts. The worst possibility is chosen. This is important for the Enterprise risk management.

In the article there are used the methods of risk management. These, which are considered here for the modelling of the extraordinary releases, are in the following Table 1.

TYPE OF SUBSTANCE BEHAVIOUR	APPLICABLE MODEL
Dispersion of gases	Gaussian model
	Box model
Jet fire	Chamberlain model
Vapour cloud explosion	Multienergy model
	TNT model

Table 1 List of models used within extraordinary accident' simulation [2]

The models are not described in detail due to the length of the paper. These are described in the [2, 6].

4. Real situation in company

The following Figure 1 reflects a situation in the company which is chosen for the modelling of the extraordinary situations. In the figure, there is a particular place in the company where two buildings are situated, the Storage of the engines and the Maintenance of the blast furnaces. The yellow line represents natural gas, the green line acetylene and the blue line coking gas. The distance between the Maintenance of the blast furnaces and the pipeline of natural gas is 0.5 m and the distance between the Storage of the engines and the pipelines of acetylene and coking gas is 15 m.

The Maintenance of blast furnace is operated in the continuous running system and in every shift there are 10 employees. Maximum two employees are in the building where the engines are stored. The operation mode is as necessary here.

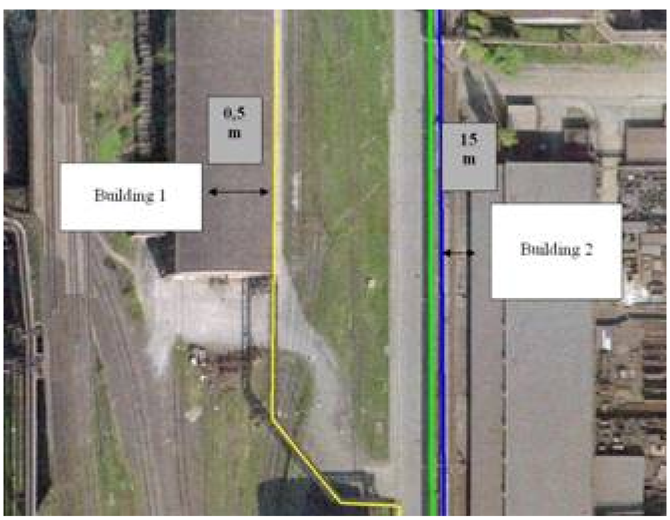

Figure 1: Real situation in company for purposes of modelling [6]

The first and the second step of the multi – criteria analysis are not considered in the paper because of its length. The content of the first step is to determine the coefficients of the particular factors. This results from the company strategy and from the implementation of the Enterprise risk management. The determination and the description of the coefficients for this type of the industrial company are included in [6] and it results from the procedure in [7]. The total average coefficient (T.A..C.) is 17,5. The detailed description of the factors is included in Table 8 below.

This chapter deals with the third step of the multi – criteria analysis.

After the assessment of the particular technological devices with a higher probability of risk, the system of pipelines which transports natural gas in the closed-off circle is chosen here.

The case study is elaborated under the real outside conditions.

The mentioned natural gas entails a certain level of risk for other technologies which arises from its physical-chemical properties and technical safety parameters. The properties of the natural gas which have an important influence in terms of loss prevention are shown in Table 2. Input data on the system of the pipeline are shown in Table 3.

GAS	COMPOUNDS	DANGEROUS PROPERTIES	LEL [%]	UEL [%]	HEATING VALUE [KJ.M-3]
Natural gas	CO_2, CH_4, N_2	F+	5	14.9	34158

Table 2 Physical-chemical properties, technical safety parameters [1]

Gas	Length	Diameter	Initial pressure	Temperature
Natural gas	6 km	DN 50	5 bar	20 °C

Table 3 Input data for computational simulations

The risk assessment is carried out using two programs, ALOHA and EFFECTSGIS, which are especially designed for use by people responding to the chemical releases, as well as for the emergency planning and the training [3, 8]. The programs model the key hazards such as the toxicity, the flammability, the thermal radiation and the overpressure related to the chemical releases that result in the toxic gas dispersions, the fires or the explosions.

The program ALOHA implements models described in [2] where uses the toxic gas dispersion, the fires and the explosions. The program employs several different models, including an air dispersion model that it uses to estimate the movement and dispersion of chemical gas clouds. The program is able to estimate the toxic gas dispersion, the overpressure values from a vapour cloud explosion, or the flammable areas of a vapour cloud.

The program EFFECTSGIS performs calculations to predict the physical effects such as the gas concentrations, the heat radiation levels, the peak overpressures of the escape of the hazardous materials. Models are based upon the [2]. It can also model the complex releases by linking individual models in such a way that they describe all physical phenomena that may occur during that release [9].

5. Modelling of scenarios

The particular scenarios were stipulated by the expert. The scenarios are carried out within the different conditions. The weather conditions are taken as the average in the location. An important circumstance in the accident simulation is the definition of the wind speed which is within the range of 1,7 and 5 $m.s^{-1}$ and north – east direction, the atmospheric stability covers the interval D to F, and the ambient air temperature is 20 ^(o)C. No inversion is considered. The gas pipeline is considered with its parameters.

Gaussian model, Chamberlain model and Multienergy model are used within the conditions of catastrophic and continuous releases. The list of simulated scenarios is included in the table 4. Scenarios with A are calculated in program ALOHA and with B in program EFFECTSGIS.

SCENARIO NO.	WIND SPEED	STABILITY CLASS	SITUATION	MODEL	TYPE OF RELEASE
1A.	5 $m.s^{-1}$	D	Release without ignition	Gaussian model	Catastrophic
2A.	5 $m.s^{-1}$	D	Release with ignition	Chamberlain model	Catastrophic
3A.	1.7 $m.s^{-1}$	F			Catastrophic
4A.	5 $m.s^{-1}$	D			2 cm hole
5A.	1.7 $m.s^{-1}$	F			2 cm hole
1B.	5 $m.s^{-1}$	D	Release with ignition	Chamberlain model	Catastrophic
2B.	5 $m.s^{-1}$	D	Release with ignition	Chamberlain model	2 cm hole
3B.	5 $m.s^{-1}$	D	Release with creation of explosive mixture	Multi energy explosion model	Catastrophic

Table 4 List of scenarios

For the chosen scenarios there are shown the results below after the computational simulations of explosions and fires. The tables 5, 6 and 7 show the results.

SCENARIO NO.	MAX FLAME LENGTH (BURN DURATION 1 HOUR)	MAX BURN RATE	TOTAL AMOUNT BURNED/ RELEASED	RELEASE RATE	FATAL ZONE	THREAT AT EVALUATED POINT (IN 0,5 M IN WEST, 2 M IN NORTH)
1A.	-	-	31.5 kg	2.5 kg. min^{-1}	< 10 m	insignificant

2A.	4 m	82.8 kg.min^{-1}	31.5 kg	-	10 m	5.18 kW.m^{-2}
3A.	4 m	82.8 kg.min^{-1}	31.5 kg	-	10 m	4.48 kW.m^{-2}
4A.	2 m	13.2 kg.min^{-1}	31.5 kg	-	< 10 m	8.1 kW.m^{-2}
5A.	2 m	13.2 kg.min^{-1}	31.5 kg	-	< 10 m	10.3 kW.m^{-2}

Table 5 List of results after modelling in ALOHA

SCENARIO NO.	AVERAGE MASS FLOW RATE (IN 40 S)	HEAT RADIATION	LENGTH OF FRUSTUM	MORTALITY	SAFE DISTANCE	VIEW FACTOR
1B.	0.12 kg.s^{-1}	21.65 kW.m^{-2}	12.58 m	64 %	23.8 m	27 %
2B.	0.05 kg.s^{-1}	0.13 kW.m^{-2}	2.49 m	0 %	3.9 m	0,2 %

Table 6 List of results after modelling in EFFECTSGIS

SCENARIO NO.	PEAK OVERPRESSURE	POSITIVE PHASE DURATION	DAMAGES	DAMAGES TO BRICK HOUSES	DAMAGES TO STRUCTURES
3B.	0.081 Bar	33 ms	Minor	habitable after repairs	minor

Table 7 List of results after modelling in EFFECTSGIS

Figures 2 and 3 show the fatal zone, the zone of second degree burns and the zone of pain including the threat at point of 0,5 m on the west and 2 m on the north from the puncture in the pipeline, within the catastrophic releasing as it considered in the scenario no. 2A.

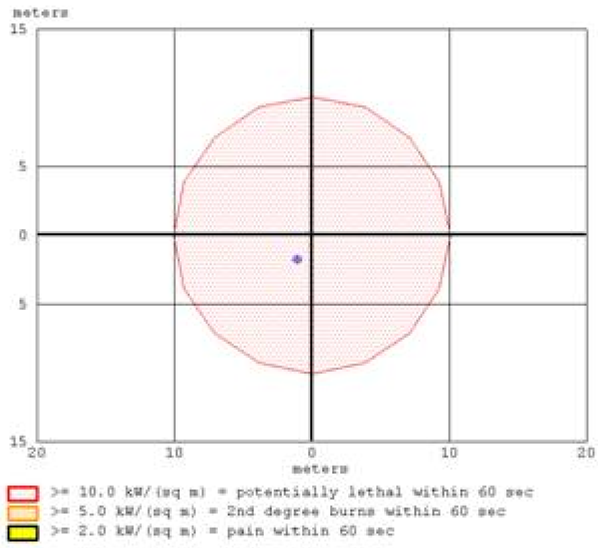

Figure 2: Threat zones within catastrophic natural gas releasing (scenario no. 2A)

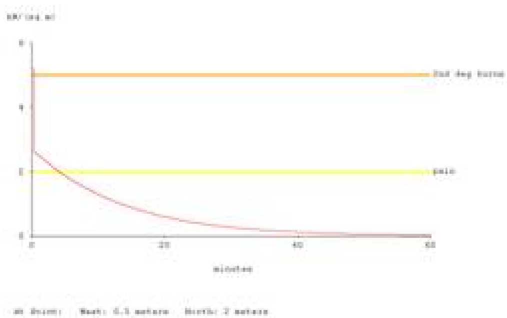

Figure 3: Threat at evaluated point (scenario no. 2A)

6. Calculation of risk

The fourth step of the multi – criteria analysis is the evaluation of the factors by the gas pipeline with the natural gas carried out by the team of the experts. This step results from the modelling of the scenarios. Results from that are usable for the purposes of the risk analysis and the emergency planning. Results are placed to the particular factors. These are described below.

The table 8 shows the separate evaluated factors with the coefficient, the evaluated aspects and the scale. The scale presented here is considered from FERMA standard [7]. This represents a possible approach of the risk management which uses the terminology for risk set out by the International Organization for Standardization in its recent document ISO/IEC Guide 73 for use in standards. The scale is transferred to the numerical one where 0 means no risk value, 1 means very low and 5 means very high. The other values in the scale are being interpolated.

T.A.C	EVALUATED FACTOR	EVALUATED ASPECT	PROPERTY OF FACTOR	SCALE
5	Human factor	Fatal zone, heat radiation, pressure zones, flame length, toxicity	Comprises the fatal, serious and other injuries	very low
				low
				middle

high				
very high				
2,5	Environment	Heat radiation, toxicity	Comprises the consequences on surrounding environment including water, costs for recultivation of land.	very low low middle high very high
3	Building structures	Heat radiation, peak overpressure, positive phase duration	Comprises damages on buildings, costs for the restoration	very low low middle high very high
4	Technical infrastructure	Heat radiation, peak overpressure, positive phase duration	Comprises possible damages on the surrounding infrastructures, following technological process breakdowns are considered	very low low middle high very high
3	Technology	Heat radiation, peak overpressure, positive phase duration	Comprises damages on particular technologies, cost of the technology	very low low middle high very high

Table 8 Risk factors and their properties [7]

The table 9 shows the calculation of the element risk factor. The experts assessed the consequences of the scenarios shown in chapter 5 including the real conditions in the company such as the number of the employees, importance of the technical infrastructure and the buildings as it results from the evaluated factors.

FACTORS	EVALUATION OF EXPERTS	TOTAL EVALUATION	T. A. C.	ELEMENT RISK FACTOR

	Expert 1	Expert 2			
Human factor	3	3	3	5	15
Environment	1		1	2,5	2,5
Building construction	2	2	2	3	6
Technical infrastructure	2	3	2,5	4	10
Technology		2	2	3	6

Table 9 Evaluation of risk in the case study

The element risk factor is 39,5. The total risk factor is calculated by division of element risk factor by total average coefficient, i.e. 39,5 / 17, 5 = 2,26.

In the case study the risk factor of the extraordinary accident is 2,26. The risk is low – middle.

The obtained risk factor of this extraordinary accident will be used for the evaluation of the total vulnerability of the considered company together with the other risks (the financial, the operational and the hazard risks).

7. Conclusion

Nowadays, the risk management is one of the most important elements of the modern company strategy. The enterprise risk management should comprise all spheres which influence the company (internal and external factors). The evaluated spheres can be for instance the financial, the strategic, the operational and the hazard risks. The important factor by the risk management is the release of the dangerous chemical substances in the industrial enterprises. The biggest force of this hazard can be found in the chemical, the metallurgical and the similar industries.

The paper deals with the evaluation and the determination of the risk factor of the release of the dangerous chemical substance. For the evaluation, the multi – criteria with the coefficients is used here.

The part of the risk management is carrying out of the countermeasures and thereby the elimination of the risk. The obtained results can be used for the emergency planning, as the important circumstance for the industrial insurance (strategic management, the cooperation of the top management and the consultant companies of the insurances companies).

References

[1] Ullmann, S. *Ullmann´s encyclopedia of industrial chemistry*. 6rd ed. Weinheim : John Wiley & Sons, 2002. ISBN 978-3-527-30385-4.

[2] *Methods for the calculation of physical effects due to releases of hazardous materials : liquids and gases : yellow book*. 3rd ed. Committee for the Prevention of Disasters (CPR), 1997.

[3] Mannan, Sam. *Lees´ loss prevention in the process industries : hazard identification, assessment and control*. 3rd ed. Elsevier, 2005. ISBN 0-7506-7555-1.

[4] *Risk management* [online]. RM Risk Management AG, c2009-2012 [cit. 2009-10-15]. Dostupný z WWW: < http://www.rmrisk.ch

>.

[5] *IRMI.com : you resource for risk and insurance solutions* [online]. International Risk Management Institute, c2000-2010 [cit. 2009-10-16]. Dostupný z WWW: <http://www.irmi.com>.

[6] Jelínková P.; Bernatík A.; Sucharda O. Risk analysis, computational simulation of accident and its influence to surround. In *The First International Conference on Soft Computing Technology in Civil, Structural and Environmental Engineering*. Stirlingshire : Civil-Comp Press, 2009. Paper 48. ISBN 978-1-905088-33-1.

[7] *A risk management standard* [online]. Belgiím : Ferma, 2009 [cit. 2009-10-16]. Dostupný z WWW: < http://www.ferma.eu>.

[8] *ALOHA user’s manual* [online]. Washington : U.S. Environmental protection agency, 2007 [cit. 2010-4-8]. Dostupný z WWW: <http://www.epa.gov/OEM/content/cameo/aloha.htm>.

[9] *TNO safety software, Effects, Damage, Effectsplus, Effectsgis.* Apeldoorn : TNO Environment, energy and process innovation, 2003.

Vzorová citace

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