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USE OF MATHEMATICAL MODELLING IN THE AREA OF EMERGENCY PLANNING

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Research article

Abstract: The paper addresses the issue of connecting the fields of emergency planning and mathematical modelling in solving industrial emergencies. The first part describes the differences in the requirements for the necessary information of the two disciplines to be interconnected. The second part deals with the proposal of a procedure for the use of mathematical modelling during incidents with leakage of dangerous substance based on theoretical and practical knowledge as well as from the results of the previously conducted survey. At the end of the paper, these proposals are presented on the model situation.

Keywords: Accident, emergency event, emergency planning, Fire rescue service of the Czech Republic, mathematical modelling.

Introduction

The term "emergency planning" refers to the set of activities, procedures and links undertaken by ministries and other administrative departments and by relevant legal or entrepreneurial individuals to plan measures to carry out rescue and liquidation work at the development of emergencies, always using achievable forces and means, e.g. the Integrated Rescue System ("IRS"). The aim of the contingency planning is to increase awareness of the potential risks, minimize their harmful effects on persons, material values and the environment and create prerequisites for the rehabilitation of the affected area (Smetana et al., 2012).

The emergency planning process results in an emergency plan. The developed purpose-built documents are called the regional emergency plan, the offsite emergency plan and the onsite emergency plan. The regional emergency plans and offsite emergency plans include the procedure for the implementation of rescue and liquidation work and other measures in the event of an accident and the leakage of dangerous substances into the atmosphere in the event of an object classified in group B being in the territory (Act 224, 2015).

For the processing of this procedure, members of the Fire Rescue Service of the Czech Republic ("FRS CR") can use mathematical modelling. By this modeling, it is possible to simulate the process of spreading the pollutant in the atmosphere and to refine the prediction of its development under certain conditions. To effectively use mathematical modelling in the area of emergency planning, it is necessary to clearly define the conditions of cooperation between the fields of emergency planning and mathematical modelling. However, there is currently no legal document regulating the use of mathematical models in the creation of emergency plans. On the basis of this, the article offers a description of requirements for the necessary information of the two disciplines in cooperation and also proposals for streamlining the communication and cooperation between the two disciplines based on theoretical and practical knowledge as well as the results of the survey (Patrman, 2018).

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The emergency planning system in the Czech Republic

Emergency planning is a type of planning and is subject to certain rules and laws. This means a summary of the measures to create the emergency preparedness of the territory (district, municipality or region) or the subject to deal with incidents arising from technical and technological accidents or the action of naturogenic events which subsequently cause such accidents. Emergency preparedness means ensuring the protection of the territory or the subject against possible consequences of the occurrence of emergencies, the ability to recognize the emergence and severity of these events or keep their course and impact to a minimum. The outcome of the emergency planning process is the creation of emergency plans, which are useful documents designed to support the implementation of rescue and liquidation work, without a declaration of a state of crisis.

The aim of the emergency plan is to create a functional plan for the event of an emergency. This functional plan is called an emergency plan. A well-conducted risk analysis should be the basis of the emergency plan. This analysis should answer questions about worst-case scenarios. For example, what type of accident would have the worst consequences? Or in what worst way will the accident evolve? What other areas can the accident affect? According to the object of interest we distinguish between: emergency planning at the level of territorial units, offsite emergency planning and onsite emergency planning. The developed purpose-built documents are called a regional emergency plan, an offsite emergency plan and an onsite emergency plan (Smetana et al., 2012).

Regional emergency plan

A regional emergency plan is a purpose-built document representing a summary of measures to carry out rescue and liquidation work, to avert or limit the immediate action of an emergency and to eliminate the consequences of an emergency. It is intended mainly as a basis for dealing with emergencies requiring the declaration of a third or special stage of alarm according to Decree No. 328 (2001). The regional emergency plan is processed by the FRS CR of the respective region under Act No. 239 (2000). To process plans, regional units of the FRS CR use an analysis of the occurrence of emergencies and the consequent threat to the territory of the region, supporting documents provided by legal entities and natural persons, and supporting documents provided by the concerned administrative authorities, municipal authorities and IRS bodies and in cooperation with them. The regional authority, regional veterinary administration, regional hygiene station and Police of the Czech Republic participate in the elaboration of partial parts of the emergency plan. The complete plan is subsequently approved by the regional governor according to Act No. 239 (2000). The structure of a regional emergency plan is described in Decree No. 328 (2001) and contains three parts: A. Information part, B. Operative part and C. Plans of specific activities. The emergency cards are then created for better clarity from plans for specific activities. At least two copies of the regional emergency plan are made. One copy is available for the meeting of the Regional Security Council and the Regional Crisis Staff and the second copy is deposited at the Regional Operational and Information Centre (IRS). The regional emergency plan is part of the regional crisis plan.

Offsite emergency plan

An offsite emergency plan is a tool for securing the territory of the emergency planning zone to safeguard the life and health of the population, environment, property and cultural values. It is prepared for two types of objects: for nuclear facilities or for category IV workplaces (workplaces with sources of ionizing radiation) and for objects classified in group B.

Nuclear facilities or category IV workplaces

This emergency plan is processed by the FRS CR region under Act No. 263 (2016). For the purpose of processing the offsite emergency plan of the territory, the emergency planning zones are divided into sectors of up to sixteen regular slices depending on the wind direction (Decree 328, 2001). There is a central space (usually circular) around a nuclear facility or category IV workplace in which the appropriate and predetermined measures are applied irrespective of the direction of the distribution of radioactive substances and irrespective of the results of the monitoring of the radiation situation. The exact course of the boundaries of the sectors and central space is adapted to the local territorial and demographic ratios. According to Annex 2 to the decree, the State Nuclear Safety Authority establishes the size of the emergency planning zone on the basis of a proposal from the authorization holder for individual activities related to the use of nuclear

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energy and for carrying out activities in exposure situations. If the zone of emergency planning interferes with the territory of one municipality with extended competence, the processed offsite emergency plan is approved by the mayor of the given municipality with extended competence. If the emergency planning zone interferes with the territory of more than one municipality with extended competence, the offsite emergency plans are approved by the regional governor (Act 239, 2000). As in the case of the regional emergency plan, the structure is listed in Decree No. 328 (2001) and is also divided into information and operational parts and plans of specific activities.

Objects classified in group B

Objects classified in group B are objects dealing with chemical substances or mixtures in which the quantity of a dangerous substance located in an object is equal to or greater than the quantity or sum of the proportional quantities of dangerous substances located in the object executed in accordance with the formula and under the conditions set out in Annex 1 to Act No. 224 (2015). The proposal for inclusion in group B shall be submitted by the operator of the object within 1 month from the date on which the quantity of the dangerous substance placed in the premises reaches at least the quantity specified in Annex 1 to Act No. 224 (2015). Its subsequent inclusion or non-inclusion is decided by the relevant regional authority. The operator of an object classified in group B is obliged, inter alia, to carry out a major accident risk assessment and to draw up a safety report on the basis of which the structure and content of each component is given in Annex 5 to Decree no. 227 of the Ministry of Environment of the Czech Republic (2015).

The operator of the facility classified in group B will further elaborate documentation for the determination of the emergency planning zone and the preparation of the offsite emergency plan. For this purpose, a methodological instruction of the Ministry of the Environment of the Czech Republic is used (ME, 2015). The operator submits the aforementioned documents to the relevant regional authority and the regional FRS. The regional authority then determines the emergency planning zone based on these. Individual emergency planning zones are part of the so-called planning analytical materials, which are forwarded to individual municipalities with extended competence and regional authorities. These documents are then an input into the process of spatial planning in the area (Blazkova and Vankova, 2018). The principles for delimiting the emergency planning zone and the procedure for delimiting it are set out in Decree No. 226 (2015). Finally, the Regional Fire Rescue Service will elaborate an offsite emergency plan in accordance with Act No. 239 (2000) within 2 years from the date of designation of the emergency planning zone. When preparing the offsite emergency plan, the regional FRS requires the cooperation of the regional authorities and municipalities and other entities, if necessary.

Particulars of the content of the offsite emergency plan and its structure are given in Annex 2 to Decree No. 226 (2015), the structuring is the same as in the case of the regional emergency plan and the offsite emergency plan of a nuclear facility or category IV workplace. The complete offsite emergency plan is then approved by the mayor of the municipality with extended competence or the Regional Governor, according to the same procedure as in the case of the offsite emergency plan of a nuclear facility or category IV workplace.

In the framework of emergency planning, Act No. 224 (2015) also stipulates the obligation for the operator of a facility classified in group B to prepare a physical protection plan and an onsite emergency plan.

Onsite emergency plan

Onsite emergency plans are designed for the organizations themselves and, as in the case of offsite emergency plans, nuclear facilities or category IV workplaces, facilities handling chemicals or mixtures classified in group B are obliged to prepare them. Operators of such facilities prepare an onsite emergency plan in cooperation with their employees and discuss it with employees of their long-term suppliers (Act 224, 2015).

If the preparer of the onsite emergency plan is also the preparer of the emergency preparedness plan or the crisis preparedness plan of the critical infrastructure entity, the onsite emergency plan must be listed in the plans prepared in accordance with the special legal regulations applicable in crisis management (Smetana et al., 2012).

Nuclear facilities or category IV workplace

In the case of nuclear facilities and category IV workplaces, the onsite emergency plan is prepared on the basis of Act No. 263 (2016) for the area of a nuclear facility or workplace with sources of ionizing radiation. It establishes measures within facilities or buildings in the event of a radiation

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accident to mitigate its impacts. The structure of this onsite emergency plan is described in Act No. 263 (2016). Content requirements are then set out in Decree No. 359 (2016). The complete onsite emergency plan is approved by the State Office for Nuclear Safety.

Objects classified in group B

Within "chemical facilities", the operator is mandated to draw up an onsite emergency plan in Act No. 224 (2015), which is a measure taken within the facility in the event of a major accident to mitigate its consequences for human and animal life and health, the environment and property. The structure of the onsite emergency plan, including the content of its individual parts, is set out in Annex 8 to Decree No. 227 (2015).

Objects not classified in group B

Emergency plans are not prepared for objects not classified in group B. However, the operator of a facility classified in group A according to the amount of hazardous substance contained in the facility listed in Annex 1 to Act No. 224 (2015) is obliged to carry out a major accident risk assessment and to develop a safety program based on it listed in Annex 3 to Decree No. 227 (2015). In the case of below-the-threshold buildings not classified in group B, which may pose a significant threat to their surroundings, a system of planning of the civil protection measures is set up to minimize the impact of a major accident (DG FRS CR, 2017). The regional FRS will carry out an assessment of the risk of a major accident, if local conditions so require, for buildings that meet any of the following conditions: a) the building is classified in group A according to Act No. 224 (2015), b) the building is not classified in group A or group B under Act No. 224 (2015), but contains the following substances: 1. anhydrous ammonia in quantities exceeding 1 t; 2. chlorine in quantities exceeding 400 kg; 3. liquefied LPG, CNG in quantity greater than 1 t. For eligible objects, the regional FRS CR subsequently determines the area of the expected spread of an emergency with consequences on the population or objects ("threat zone"), the method of determination of which is specified in the direction of the Director General of the Fire Rescue Service of the Czech Republic ("DG FRS CR"). On the basis of the risk assessment, it is then decided whether, in the event of a major accident, a below-the-threshold building could pose a significant threat and for this reason it is necessary to process an emergency card for the substance.

OPTIZON

In order to unify the procedures for establishing the emergency planning zone, the OPTIZON security project was conducted in 2011-2013 (Dlabka, 2015). The full title of this project is *Optimization of Emergency Planning Zone and Emergency Plan Creation Based on Hazardous Manifestations of Hazardous Chemical Substances in Operational Accidents with a view to Increasing Civil Protection.* One of the main activities during the project was to determine the actual method of calculating the distance of the emergency planning zone for the defined scenarios relevant to the accidents under consideration within the companies under the jurisdiction of, then in force, Act No. 59 (2006). The scenarios were defined according to the categories of dangerous substances identified under the SEVESO III Directive (EC, 2012). The project dealt with a larger number of scenarios, but only the scenarios that are actually capable of causing a threat to the population outside the chemical enterprises classified in group B according to the Act No. 59 (2006) were considered in the final calculation method.

The OPTIZON project was launched due to shortcomings in, then in force, Decree No. 103 (2006), which regulated the determination of the emergency planning zone (Baudisova et al., 2012). This Decree was based on the principles of IAEA-TECDOC-727 (Bernatik, 2006). The method itself points out that it is not suitable for the creation of an emergency plan for special (emergency) situations (industrial activity in a populated area). Nevertheless, its principles and procedures were used for this purpose under Czech conditions.

The most important benefit of the OPTIZON project was the creation of a new method of determining the emergency planning zone, which was subsequently incorporated into Decree No. 226 (2015) and the creation of the auxiliary software tool Optizon (Blazkova and Vankova, 2018). Both of these project outputs are now crucial for establishing emergency planning zones.

Survey

In order to obtain information from the FRS CR, a survey was created (Patrman, 2018). The survey was then sent to the individual regional directorates of the FRS CR. Out of the total of 14 directorates addressed, eight were able to obtain answers. The survey consisted of the following questions:

1) Do you use any of the mathematical modeling tools (ALOHA, TerEx, Rozex Alarm, ANSYS…) for emergency planning? If so, which one and for what specifically.
2) Have you used a modeling expert(s) for modeling?
3) What input data had to be delivered to modelers for modeling needs and by what time?
4) Was it difficult to obtain this data?
5) On the contrary, what output data (results) did you ask the modelers and by what time?
6) Was the time of delivery of the output data satisfactory for you?
7) Was the content of the output data sufficient and useful for you?
8) How long did the process itself take (from the assignment to the results)?
9) Have there been any misunderstandings or confusion while communicating with modelers? If so, what misunderstandings and why.
10) In your opinion, is there anything that could improve or streamline communication and information exchange between emergency planners and mathematical modelers?
11) Do you think that mathematical modeling is generally useful for emergency planning?

The answers show that the approach to the use of mathematical modeling tools in the field of emergency planning differs within individual FRS CR regions. Indeed, there is no legislative document that orders or prohibits its use. It is therefore up to the individual FRS CR regions whether or not to use modeling for their needs. The use of modeling tools was reported by 5 respondents, 2 of whom said they had used them in the past but are no longer working with them. The remaining 3 have also confirmed their current use for modeling leakages of hazardous substances. As far as the tools are used, the most frequently mentioned software was ALOHA (5x) and Rozex Alarm (2x). A total of 5 directorates said they favor OPTIZON over mathematical modeling. Some directorates also expressed some skepticism about pre-emergency modeling, because in order to cover all possible scenarios it would be necessary to model so many situations under different conditions that their modeling is not absolutely effective in terms of future outcomes. When dealing with an emergency, there is not enough time for detailed model calculations, which plays an important role in these situations. However, rapid modeling (around 15 minutes) using statistical models can help create at least an approximate picture of the evolution of the situation. However, the question is whether the resulting data will be relevant in view of the large number of possible variables dependent on the scenarios mentioned in the following chapters of this work. Moreover, the detailed modeling of one event into several variants, e.g. for gaseous chemicals, is not required in advance. The cooperation with external modelers was not confirmed by any of the interviewees with the fact that they have their own staff with the appropriate knowledge for the use of modeling. One respondent stated that in the past, discussions were held with the other party on the possibility of collaborating on a project where mathematical modeling would be used. But in the end, for unspecified reasons, the cooperation failed.

Requirements for emergency planning

Responsible persons involved in emergency planning ("emergency planners") and working with mathematical modeling tools, use them mainly in cases of leakages of dangerous chemicals. Most often it concerns the modeling of toxic substance leakages, to a lesser extent it is also used for flammable, explosive or possibly oxidizing substances, especially for the determination of the emergency planning zone for objects classified in group B (Act 224, 2015) and for the determination of the danger zone for other objects for which the zone needs to be determined. The content of the emergency card is specified in Article 7 of the directive (DG FRS CR, 2017). The following information is crucial for emergency planners within these zones.

Total area affected

A well-defined total area of exposure to a hazardous substance is a prerequisite for the following emergency planning procedures. The procedure for determining the emergency planning zone is defined in Decree No. 226 (2015). The identification of emergency zones for emergency cards was not subject to any legislative changes before 2017. In practice, there have been cases where the same technologies, such as the engine room cooling of ice hockey arenas, with the same amount of ammonia, were evaluated differently and the calculated threat zones varied across the territory by hundreds to thousands of meters (Patrman, 2018). Since 2017, the determination of danger zones has been classified in the directive (DG FRS CR, 2017), which also mandates regional FRS CR to prepare emergency cards of the FRS CR region according to a unified procedure no later than by the beginning of 2019. The procedure mentioned in the directive is in line with Decree No. 226 (2015) and de facto also with the OPTIZON system (Blazkova and Miklos, 2014). The results of the survey (Patrman, 2018) show that the OPTIZON system is currently widely used for the determination of emergency planning zones and danger zones by individual regional FRS CR.

Two types of borders are used to define the emergency planning zone, the “external border” and “initial border”. The initial border is defined as the minimum area in which, in the case of the implementation of the type scenario, the measures of the civil protection are applied for the risk of hazardous substances (i.e. informing the surrounding population, the possibility of evacuation from significant buildings, closures of the endangered area, etc.). The procedure for calculating the radius of this limit is given in Annex 1 to Decree No. 226 (2015). The external border is then fixed from the initial border as the final border of the emergency planning zone, by adjusting to urban, terrain, demographic or climatic conditions, or other factors worthy of consideration, taking into account the possibility of a domino effect. The following principles are gradually taken into account in the adaptation (Decree 226, 2015): the external border may be set to: 1) take into account conditions affecting the dispersion of hazardous substances, the spread of heat or pressure waves, and 2) not separate individual houses or dwellings, or separate inhabited areas with regard to the nature and intensity of the threat and planned measures of the civil protection. Furthermore, the external border must take into account parts of the borders of the administrative territories or, where appropriate, the borders of the land, if the boundaries of the administrative territory or the boundary of the land cannot be used.

In the case of using mathematical modeling tools as an auxiliary tool for the determination of the aforementioned zones, the most accurate definition of the borders of these zones are required by regional FRS CR during the period outside the emergency. At least an approximate demarcation of the borders is required during an emergency, with more emphasis on the time of delivery of results than on complete accuracy. In both situations, acceptance of the results is conditioned by the following.

Limit concentrations of hazardous substances in the atmosphere

The designated zones would not in themselves be meaningful unless the limit concentrations of the dangerous substance in the air within these zones were defined at the same time. Based on these concentrations, the limits of acute toxicity for individual areas of zones will be determined in relation to the implementation of measures to protect the population and the necessity of the self-preservation of citizens. However, there is no general agreement on the use of individual limits of acute toxicity, either internationally or at the level of the Czech Republic. According to the study (Baudisova et al., 2009), the most frequently used limits of acute toxicity in the Czech Republic are LC_{50}, ERPG-1,2,3 and IDLH.

Leakage time

An important input condition for eventual modeling is the definition of the time elapsed since the start of the leak, as the concentration of hazardous substances and the gradual development of the toxic cloud changes dynamically over time. The situation within 1 minute from the start of the leak may differ significantly from the situation, e.g. in the 10^{th} or 30^{th} minute. Knowledge of the development of the situation is absolutely necessary for emergency planners, but its exact determination is very difficult due to the many variables that affect the situation (the type and amount of the leaked substance, air temperature, wind direction and strength, etc.).

The situation will also look different in a situation where the substance has not been leaking for some time, i.e. in time passed since stopping the substance from leaking into the air.

Meteorological conditions

The modeling of the development of the post-accident situation and related scenarios is highly dependent on meteorological conditions. However, for emergency planning purposes it is absolutely necessary to define for which meteorological conditions the given situation was modeled. Thus, the results provided without this information will only be relevant in a limited number of cases.

Crucial information is mainly the direction and strength of the wind. The movement and scattering of the toxic cloud depends on this. Another necessary indication is the temperature of the atmosphere, which may, for example, influence the rate of evaporation of the substance into the atmosphere when a liquid substance leaks. The fact that air temperature also depends on air temperature in a warmer environment, some substances become more rapidly heated, decrease in density, and reduce the tendency to descend to the ground (Zavila et al., 2014).

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Requirements for mathematical modeling

The required input data from modelers to meet the needs of emergency planners may differ significantly from the data available to emergency planners. However, planners should be aware of the necessary data in advance. Input data requirements will also vary depending on the modeling software selected. For correct modeling results, it is necessary to know the following data in advance.

Modeled area

Especially for CFD tools (Hu, 2012) it is necessary to clearly define the area in which the emergency scenario will be modeled. This then serves as a starting point when creating the calculation area. The following data is important within the modeled area. The first information needed to start modeling the area is their dimensions, which can be defined, e.g. by GPS coordinates. Within the designed area, the type of the area, e.g. open space, urban development or water area, is chosen based on the provided geographical data. When working with CFD tools, individual buildings, structures, mounds and other natural and man-made obstacles are then modeled. Last but not least, it is necessary to determine the height relative to the Earth's surface at which the modeling will take place. There may be different concentrations of the dangerous substance at different altitudes and the resulting values may vary greatly.

Defining dangerous substances

First, it is necessary to identify the dangerous substance itself, which is considered in the modeled scenario. Some modeling tools have their own database of substances, including their physicochemical properties, which define its behavior in the modeled situation. In these cases, the name of the substance or its chemical formula is sufficient to identify it. When modeling, the substance is either selected from a pre-set database or it is necessary to supply information about the substance and then insert it into the used software "manually". Among the physicochemical properties required, mention may be made of, for example, physical state, molar mass or boiling point.

Method of storage of the substance

The operator of the facility handling hazardous substances should provide information on how to store it for modeling purposes. This data can then help in getting closer to reality during modeling. Especially useful for modelers is information on the state of the substance and at what temperatures the substance is stored. Furthermore, what is the volume of the substance and under what pressure is it stored?

Meteorological conditions

As well as for emergency planners, meteorological data are also a crucial point for modelers, from which the course of the modeled scenario is based. While the force and direction of wind and air temperature are sufficient information for emergency planners, mathematical modelers require more detailed information. In addition to the aforementioned strength and direction of wind and air temperature, which are also crucial for modelers, modelers may also require data about local atmospheric pressure, air humidity, or the atmosphere stability class. Alternatively, an inverse situation may be classified in the modeling. The Czech Hydrometeorological Institute ("CHMI") is a reliable provider of all these data. It is able to provide comprehensive and very accurate weather data from its stations throughout the Czech Republic. Furthermore, it is also possible to request meteorological data from controlled airports in the vicinity of the modeled accident.

Proposal of the procedure for the use of mathematical modeling in the solution of emergencies with the release of dangerous substances

This chapter deals with the idea of how to make the interconnection of both fields more effective in practice. At the end of the chapter there is a suggested solution for meeting these goals.

Evaluation of the current state

At present, no legislation requires the use of mathematical modeling to deal with an emergency or during the planning process. Each regional FRS CR thus resolves the situation "in its own way". This also implies a different experience of emergency planners with mathematical modeling (Patrman, 2018). With varying degrees of experience, mathematical modeling also involves a different knowledge of modeling tools. The lack of knowledge of modeling tools and the whole modeling process may give rise to skepticism about the benefits of mathematical modeling and the establishment of an overall different philosophy of emergency planning,

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which puts mathematical modeling at the margins of interest. A different philosophy is meant here when the emergency planner shows interest in cooperation with a mathematical modeler, but is not fully familiar with the modeling process. This process, which also involves preparation in the form of collecting the necessary data, appears to the emergency planner to be too lengthy and demanding, and therefore he prefers to solve the situation in a less complex way and without using mathematical modeling.

Problems can then occur between the two areas when emergency planners are not familiar with the need to supply the necessary modeling data and its content or in situations where both parties use different terminology during communication, which in turn causes misunderstandings and the misapprehension of requests by the other party. This situation may result in incorrect input or output data and the overall non-fulfillment of cooperation.

Prerequisites for beneficial cooperation

There are two key prerequisites for working cooperation between emergency planners and mathematical modelers. The first is the motivation for using mathematical modeling. It is necessary to show the usefulness of modeling and to convince emergency planners that it pays off to devote time and effort to understanding its principles. Without sufficient demonstration of usefulness, modeling may appear to be an unnecessary and complicated tool for which there is no room for emergency planning. The usefulness and potential of mathematical modeling will be particularly apparent in situations where non-standard conditions exist in a major accident, the probability of which is very low, and therefore this scenario variant is not foreseen during planning. Testing the situation in real conditions would be almost impossible due to the low occurrence of the conditions. However, mathematical modeling is also beneficial in other situations. The second prerequisite is the willingness of both aforementioned fields to seek new ways and methods to resolve the problems that arise. Both sides should strive to understand the situation from each other's perspective and to maintain a calm and friendly atmosphere. The aim of all this should be to streamline cooperation and reduce overall modeling time.

A suggested solution

In order to prevent the creation of problems between the two branches during their interconnection, it is proposed that the selected person having emergency planning in their competence (i.e. members of the regional FRS CR and regional office employees) is also trained to work with mathematical models.

Such persons (hereinafter referred to as "experts") would then be trained jointly at certain intervals in a single training center. The training center would be, for example, the building of the Faculty of Safety Engineering of the VSB - Technical University of Ostrava in Ostrava. Experts would be trained in the knowledge and correct use of selected modeling tools and would also be presented the usefulness of mathematical modeling and the benefits of its use in emergency planning, including demonstrating these benefits on specific cases. The training would also emphasize the knowledge of the terminology framework and knowledge of the necessary input data for modeling, their collection and the comprehension of these data. During the training, the experts would also learn to properly evaluate modeling results, relate them to specific conditions, and implement them in the emergency planning process.

In practice, these experts would be obliged to use the acquired knowledge during the mathematical modeling of emergency scenarios around predetermined objects loading with dangerous substances. Thus, it would not be a problem for trained experts to prepare a number of scenarios for different conditions in the preparation of emergency plans and cover as many scenarios as possible. In addition, experts would be available for real-time modeling while on duty, particularly in situations where it was not possible to model the circumstances in advance (e.g. leakage of a hazardous substance during a transport accident) or when their interaction is required during an emergency.

Model situation

On June 4, 2019 at 13:13, the escape of ammonia gas from an ice rink located in an urban area is reported at the operating center. The expert obtains information about the area where the ice rink is located and identifies its exact location from the electronic map data (see Fig. 1). Based on the available information, the expert starts to model the leak. The expert chooses freely available ALOHA software for modeling because of the relatively fast results (EPA, 2017). The expert selects the leaked substance - ammonia (NH_3) from the software database. Subsequently, it enters information on the manner of storage of the substance provided by the operator of the ice rink and current meteorological data. The tank in the stadium contains 4 tons of liquid ammonia, the total mass flow rate of the mixture of ammonia and air was set at

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1.583 kg/s, the mass fraction 0.37. The mass flow rate is then determined to be 0.586 kg/s. with a leak time of 30 minutes. Based on the meteorological data provided, the currently prevailing wind direction SW (225°) is selected - it is also the most frequent wind direction in this area, while the temperature (20 °C) and humidity (30 %), air stability class (A) and wind strength (2 m/s) correspond to the current situation and season. The acute toxicity limits are set to the ERPG limits. The resulting zones are displayed in GIS (see Fig. 2).

In the depicted zones, it identifies objects that have a high probability of being hit by a toxic cloud. It then orders an evacuation for objects in the red zone (ERPG-2). Objects located in the orange zone (ERPG-1) will not be evacuated, they will only be advised to close windows and doors and turn off air circulation from the outside.

Fig. 1 Location of the ice rink in urban area (Google, 2019)

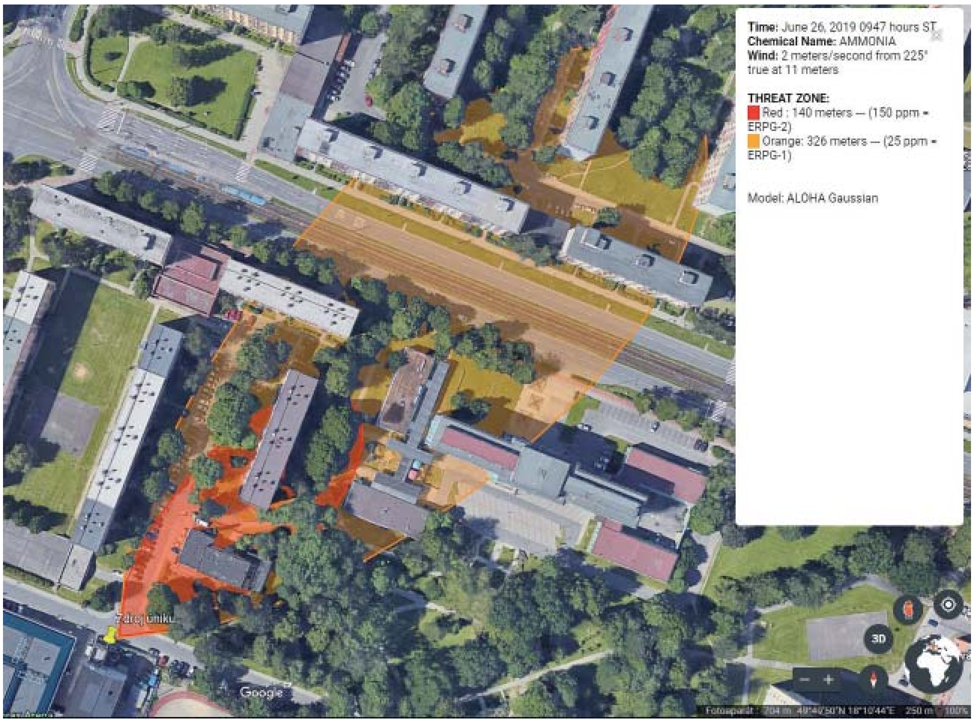

Fig. 2 Toxic cloud spread zone (Google, 2019; EPA, 2017)

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Conclusion

There are differences between the requirements of both mathematical modeling and emergency planning in input and output data requirements for emergency responses. In each of these disciplines, four key requirements were set and subsequently justified. The key requirements for emergency planning are output data in the form of defining the total area affected, limit concentrations of hazardous substances in the air, leakage times and meteorological conditions. In the case of mathematical modeling, these are input data requirements in the form of defining the modeled area, hazardous substance, storage method and meteorological conditions. There is a consensus within the requirements of both branches, especially in the area of the need to obtain meteorological data. Other requirements differ in some ways. The proposed procedure for the use of mathematical modeling in dealing with emergencies with dangerous substance leakage then consists in entrusting selected persons with emergency planning in their competence with mathematical modeling. They would then use it during emergency planning and in the direct handling of emergencies with dangerous substance leaks.

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