Zeszyty Naukowe SGSP 2020, Nr 74/2/2020

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DOI: 10.5604/01.3001.0014.3022

Computer Programmes for Determining the Probability and Consequences of Major Accidents

Abstract

The article presents an overview of the most popular available computer programmes in Poland used to support the implementation of particular stages of the process of risk analysis and assessment for lower or upper tier establishments. Particular attention was focused on the advantages and disadvantages of particular programmes, taking into account their functionality, availability, ease of use, as well as the reliability and validation of the results obtained. The appropriate selection of a program to determine the hazard zones, consequences, frequencies, and risk indicators of accident scenarios allows designing adequate safety and protection measures to be adopted in the event of occurrence of such undesired events. It also facilitates the preparation of risk maps as well as internal and external operation and emergency plans.

Keywords: risk analysis, computer programmes, physical effects and consequence modelling

Received: 30.11.2019; Reviewed: 03.04.2020; Accepted: 12.06.2020

Programy komputerowe do wyznaczania prawdopodobieństwa oraz skutków poważnych awarii

Abstrakt

W artykule przedstawiono przegląd najbardziej popularnych i dostępnych w kraju programów komputerowych wspomagających wykonywanie poszczególnych etapów procesu analizy i oceny ryzyka dla zakładów dużego i zwiększonego ryzyka wystąpienia poważnej awarii przemysłowej. Szczególną uwagę skupiono na zaletach i wadach poszczególnych programów, biorąc po uwagę ich funkcjonalność, dostępność, łatwość użycia oraz wiarygodność i walidację uzyskiwanych wyników. Właściwy dobór programu (do określenia wartości zasięgu stref zagrożeń i konsekwencji, częstości wystąpienia skutków scenariuszy awaryjnych, wskaźnika ryzyka) pozwala zaprojektować adekwatne środki bezpieczeństwa i ochrony na wypadek wystąpienia takich zdarzeń niepożądanych. Ułatwia również przygotowanie map ryzyka oraz wewnętrznych i zewnętrznych planów operacyjno-ratowniczych.

Słowa kluczowe: analiza ryzyka, programy komputerowe, modelowanie skutków awarii

Przyjęty: 30.11.2019; Zrecenzowany: 03.04.2020; Zatwierdzony: 12.06.2020

Комп›ютерні програми для визначення ймовірності та наслідків великих аварій

Анотація

У статті представлено огляд найпопулярніших та доступних в країні комп’ютерних програм, що допомагають в реалізації окремих етапів процесу аналізу та оцінки ризику для підприємств з високим і підвищеним ризиком великої промислової аварії. Особливу увагу зосереджено на перевагах і вадах окремих програм, враховуючи їх функціональність, доступність, простоту використання, а також надійність та достовірність отриманих результатів. Відповідний вибір програми (для визначення ступеня зон загрози та наслідків, частоти виникнення наслідків аварійних сценаріїв, показника ризику) дозволяє розробити адекватні заходи безпеки та захисту у разі виникнення таких несприятливих ситуацій. Це також полегшує пртготування карт ризику, внутрішніх та зовнішніх операційно-рятувальних планів.

Ключові слова: аналіз ризику, комп’ютерні програми, моделювання наслідків аварій

Прийнятий: 30.11.2019; Рецензованої: 03.04.2020; Затверджений: 12.06.2020

1. Introduction

To counteract consequences of serious industrial failures by virtue of the law, operating and rescue plans need to be devised, both internal and external ones. They may be formulated on the basis of guidelines for the Seveso III Directive 2012/18/EU of the European Parliament and of the Council of 4 July 2012 on the control of major-accident hazards involving dangerous substances [1], which have been allowed for in the act of 27 April 2001 *The Environment Protection Law* (Polish Journal of Laws/Dz.U. 2018 item 799) and implementing regulations [2–7]. The Act *The Environment Protection Law* is applicable and binding to any operator who intends to run or is running an industrial plant (lower-tier establishment or upper-tier establishment), i.e. those that use appropriate amounts and type of chemical substances or their mixtures to make sure that such a plant had been designed, implemented, operated and closed down in a way that assures industrial failures and limiting their consequences for people and for the environment.

The plant operator needs to prove that it is correctly managing process risk. Risk management is understood as a set of organisational and technical measures oriented at systematic analyses, evaluation and control of risk to prevent and secure from consequences of serious industrial failures. Those actions are to strive at making a selection of protection means that will allow achieving the admissible risk level.

An operator of a lower-tier or upper-tier establishment needs to assure safety of the employees, population, environment and property from potential consequences of those failures. Such an operator is also obliged to analyse possibilities of occurrence of an industrial failure and taking up measures necessary to prevent it. This analysis is based on identification of hazards, assessing the risk magnitude by defining the likelihood of occurrence of an emergency scenario and the scale of its consequences. Risk analyses may be implemented by applying appropriate methods and tools. Different risk analyses and assessments are used: quantitative ones (e.g. ARAMIS), semi-quantitative ones (e.g. AWZ, ExSys-AWZ) as well as qualitative ones (e.g. FMEA, PHA, HAZOP, What-If, error tree, tree of events, risk matrix). The actual selection of the method depends on many factors: they include available input data for the analysis, complexity of the installation and the time that can be dedicated to the analysis. The process of devising an analysis of industrial risk is a task that needs to be executed by an expert that requires assuring a group of experienced specialists from a few disciplines, pertinent figures, and in addition its implementation is time-consuming and entails several uncertainties of epistemic and stochastic nature, e.g. related to the accessibility of infallibility data, their credibility. Once the risk analysis has been carried out, it should be appraised on the basis of appropriate acceptance criteria. In Poland there are no set formal guidelines pertaining to those criteria, and consequently such liability falls onto establishments bound by the Seveso Directive. If the risk being assessed is acceptable, there is no need to make attempts at reducing it [8, 9]. On the other hand when risk is unacceptable as compared to selected criteria for risk acceptance, appropriate measures need to be undertaken to have such risk minimised, for example by adopting additional safety means (comprising physical barriers, organisational and legal actions and method of minimising consequences of undesired events) or enhancing the existing ones.

2. Review of programmes for modelling the likelihood and consequences of serious failures

To facilitate calculations executed by safety analysts drawing up documentation for low-tier and high-tier establishments, computer programmes have been developed to assist the implementation of particular stages of the process risk analyses and assessment.

In the process of identifying hazards and selecting representative emergency scenarios use is made of the ExSysAWZ programme, which had been developed by scientists from the Department of Process Engineering and Environment Protection of the Łódź University of Technology. The ExSysAWZ programme may be used to generate emergency scenarios related to the release of hazardous substances for needs of an assessment of risk of occurrence of a serious emergency with the use of layer of protection analysis (LOPA). The ExSysAWZ packet also comprises the DaneExSysAWZ programme, which is designated for editing data bases concerning hazardous substances, unit processes, process hazards, emergency incidents, triggering incidents, matrix of process hazards, logic trees, and relations between emergency incidents with triggering incidents. For a hypothetical fuel base this method, based on a list of 13 emergency incidents typical for industrial processes, has generated over 105 scenarios [8]. A printout of two illustrative examples of scenarios modified using the ExSysAWZ programme was presented on fig. 1.

In practice the biggest difficulties faced by risk analysts are posed by the process of assessing the likelihood (or frequency) of occurrence of various consequences under a emergency scenario. In the first place this is an effect of problems related to access to infallibility data that characterise all elements forming the scenario and a complex computational process. To avoid the above mentioned problems, scientists from the

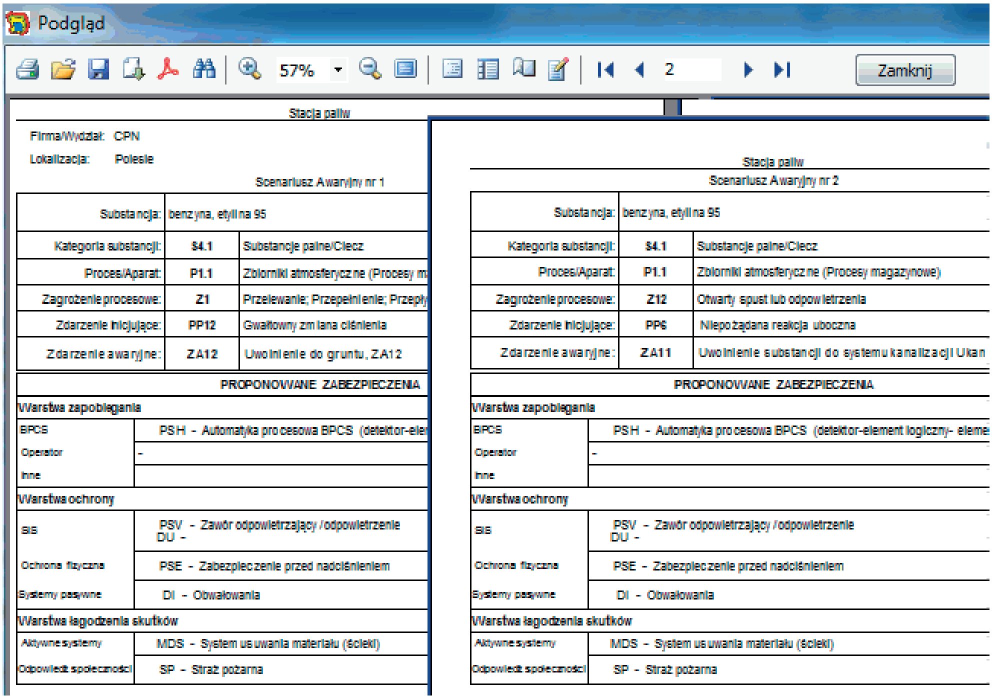


Fig. 1. Illustrative two scenarios generated using the ExSysAWZ programme for further analyses in the AWZ programme

Source: [8]

Department of Process Engineering and Environment Protection of the Łódź University of Technology has developed an informatics tool - LOPA, which is meant to assist the process of assessing the frequency of occurrence of consequences of emergency scenarios and risks for the operating or planned installations. The method of layer of protection analysis, implemented in the LOPA packet, has been based on the identification of ascertained multi-layer protections and the probability of their failure. It assumes that a serious emergency occurs as a result of inefficiency of safety systems, and in addition allows appraising the effectiveness of the used or planned layers of protection. The LOPA packet consists of two programmes: the AWZ programme and the data editing programme - DaneAWZ. The AWZ software allows executing the proper LOPA analysis that consists of three stages: determination of the frequency of consequences of an emergency scenario without protection means, determination of the frequency of consequences of an emergency scenario with protection means and assessment of the risk of occurrence of the given emergency scenario on the basis of the risk matrix and adopted acceptability principles. The Dane AWZ programme is used to edit data necessary to carry out the analysis, i.e. infallibility data for trigger events, conditioning events and the likelihood that protections would fail in three layers: prevention, protection, counteracting; data base of hazardous substances; matrices of consequences, risk and domino effects. An illustrative printout from the AWZ software has been shown on Fig. 2.

Politechnika Łódźka, Katedra Inzynierii Bezpieczeństwa Pracy — Analiza Warstw Zabezpieczeń dla scenariusza 4 : — str. 1/1

Synthos S.A. Centralny Magazyn Butadienu Wydział Kauczuku – Dział Monomerów i Emulgatorów **Lokalizacja**: Oświęcim, ul. Chemików 1	**Proces:** Magazynowania **Aparat/urządzenie:** Króciec DN125 zbiornika lp.16	**Rodzaj zdarzenia:** RZA (W) **Nazwa zdarzenia:** Rozszczelnienie króćca DN125 zbiornika magazynowego 1,3-butadienu lp. 16	
Data analizy: **8-03-2016** **Substancja:** 1,3 butadien	**Opis scenariusza zdarzenia awaryjnego:** Rozszczelnienie króćca **DN125 zbiornika magazynowego 1,3-butadienu lp.16 (T=20°C, P=0,3 MPa, całkowita pojemność zbiornika 50 m3, stopień napełnienia 80%) wskutek powstania polimeru popcornowego. Wypływ substancji na wysokości 2,5 m w kierunku pionowym do dołu na tacę podzbiornikową (powierzchnia tacy 155,2 m2, wysokość murka 0,1m) do czasu opróżnienia zbiornika. Niezadziałanie detektorów i niepodjęcie działań przez obsługę eksploatacyjną. Zapłon mieszaniny palnej i skutki pożarowo – wybuchowe.**		
Stopień uwolnienia: 5 do 50000 kg Obszar: Magazynowy	**Ocena kategorii skutków:** 5 katastrofa	**Ocena ryzyka**	
		PFD	Częstość (1/rok)

Zdarzenie inicjujące			
	Powstanie polimeru popcornowego		**0,1**
Zdarzenia warunkujące wystąpienie scenariusza awaryjnego			
	Błąd operatora	**0,01**	
Zdarzenia umożliwiające powstanie skutków wymienionych w scenariuszu, zewnętrzne			
	Prawdopodobieństwo niesprzyjającego kierunku wiatru		
	Prawdopodobieństwo zapłonu - zapłon natychmiastowy	**0,45**	
	Prawdopodobieństwo pobytu w strefie		
	Prawdopodobieństwo śmierci	**0,5**	
	Efekty domina	**10**	
	Częstość wystąpienia skutków bez zabezpieczeń:		**2,3e-03**
Niezależne warstwy zabezpieczeń (NWZ)			
Warstwa II (Ochrona)			
	Detektory gazu	**0,01**	
Warstwa III (Przeciwdziałanie)		Zmiana Kat. Skutków	
	Działania Zakładowej Straży Pożarnej w ciągu 5 do 10 min.(od -1 do -2)		**-1**
	Kategoria skutków po korekcie		**4**
	Końcowe prawdopodobieństwo dla wszystkich NWZ	**0,01**	
	Częstość występowania skutków z zabezpieczeniami		**2,3e-05**
	Ocena kategorii ryzyka		**TA**

Dodatkowe zabezpieczenia niezbędne do osiągnięcia poziomu ryzyka co najmniej **TA**	**nie dotyczy**
Referencje, odsyłacze	Raport o Bezpieczeństwie RoB część II/1; Layer of Protection Analysis, CCPS, AICHE (2001)
Zespół analizujący	A.S. Markowski, D. Siuta

Fig. 2. Illustrative sheet from the AWZ programme

Source: [10]

The AWZ and exSysAWZ programmes are user friendly and require less time to devise analyses of process risk. The programmes have been provided with user manuals in Polish (guide book), which guide the user step by step through the application. The above mentioned programmes do not require the installation of additional libraries or system resources. The risk analyst executing the analysis with the use of this type of programmes must be appropriately trained, and must additionally have practical experience and knowledge. The minimum time required for appropriate effective handling of the AWZ and exSysAWZ software is 5 days.

The next serious challenge for a risk analyst is the process consisting of the delimitation of impact zones of particular physical effects, the so-called hazard zones based on mathematical models that describe among others features of the release source, spreading process of the spill, vaporisation, dispersion of gas clouds and finally, after the occurrence of the source of ignition, the process of combustion of the flammable mixture with physical effects, such as shrapneling, thermal radiation and an overpressure wave [11]. The modelling process of ranges of hazard zones and effects of release of hazardous substances may be implemented with the use of such computer programmes, as: Aloha (U.S. EPA), Rizex-2 (RIZIKON), Breeze Incident Analyst (Trinity Consultants), Canary (Quest), Effects (TNO) or Phast (DNV). Further on a discussion was presented of the most popular software for modelling consequences of technical failures in Poland.

CHARM

The development of the CHARM software has been commenced by Dr. Mark Eltgroth in 1981. It is the most extensive simulation programme from among those in common use, as has been presented in Table 1. The current version of the programme enables modelling of emergency release of hazardous substances, toxic dispersions and flammable substances, fires and explosions. Two versions of the CHARM software are available. The first one of them may be used to model one hazard source on a flat terrain. The second version allows the representation of many hazard sources in a 3D terrain. The version based on a flat terrain is also available as an internet application, and may be accessed via an internet browser; furthermore, it does not require any special software. Both CHARM versions may be used to assess the impact of the use of chemical mass destruction weapons. Both data bases comprise parameters of munitions, which may for example be used in terrorist attacks (such as chlorine, mustard gas, sarin, soman and VX). It also allows assessing the consequences of the use of biological mass destruction weapons (e.g. anthrax bacteria). The programme version with the 3D representation enables the implementation of a complete simulation for a real location (based on Google maps). Many chemical substances used in mass destruction weapons are released in the form of aerosol. The complex version of CHARM is capable of simulating all chief processes that affect aerosol. It is necessary to make a failproof assessment of the amount distribution of aerosol in the released chemical substance. Following the release, CHARM may calculate changes to the size distribution as an effect of coagulation, condensation, vapouring and settlement. Possibilities of modelling the hazard that arises from the use of biological weapons in the CHARM 3-dimensional version take into consideration the form of aerosol (calculations pertain to concentrations in the air) or the settled form of the substance [12]. Fig. 3 shows illustrative calculations concerning ranges of thermal radiation zones during a surface petrol fire.

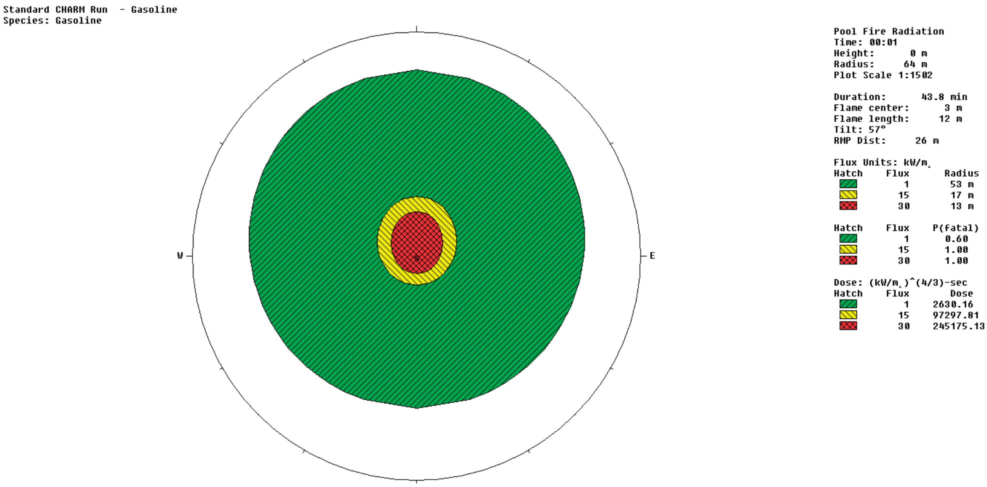


Fig. 3. Range of particular hazard zones depending on the density of thermal radiation flux for a surface fire of petrol

Source: own study based on the CHARM programme

EFFECTS

EFFECTS is advanced software from the Netherlands meant to assist safety analyses for the petrochemical, refinery and chemical industry throughout the entire technological process. The programme offers a full range of computational models concerning emergency events and incidents connected with the storage and transport of chemical products – ranging from temporary release, continuous release, evaporation of liquids, gas dispersions, up to fires, explosions and their consequences for the surroundings. The specified models may be combined and selected individually or the programme may do this automatically. It contains an advanced data base of toxic, flammable and explosive substances (thermodynamic properties of more than 2000 chemical compounds). The integrated editor allows detailed definitions of own substances, produced or stored substances or chemical mixtures. The consequences of the ascertained events are modelled, and the results are presented in legible tables, diagrams or maps, where there are visualisations of the effects of the adopted emergency scenario.

Results of the simulations provide to safety specialists valuable information concerning possibilities of the occurrence of relevant physical phenomena in the given emergency scenario, range sizes of impact zones of a flammable or toxic cloud, overpressure wave caused by an explosion, thermal radiation from the fire. Application of the EFFECTS software offers obtaining credible effects and it is considered on the international arena as referential for analyses of event consequences. This software, which has been implemented by the Netherlands Organisation for Applied Scientific Research, is still being developed, and has been in use for many years in production plants, by government agencies and research institute the whole world over [13]. Fig. 4 presents a result of an illustrative simulation of the impact exerted by thermal radiation from a surface fire of a petrol tank.

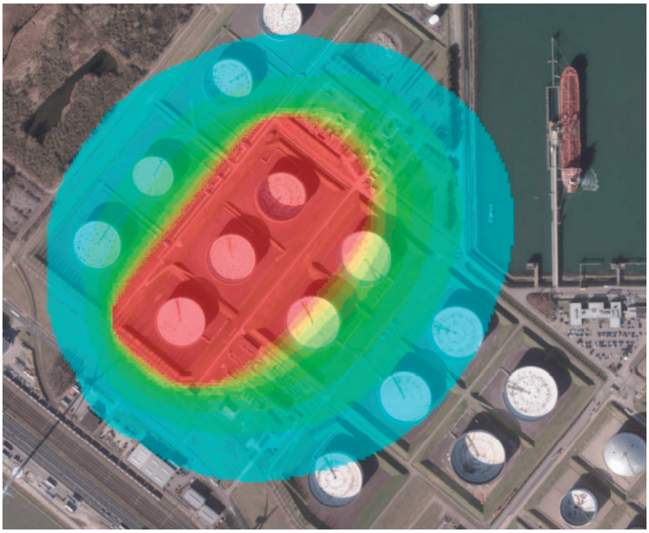


Fig. 4. Advanced modelling using the EFFECTS software related to tank fires

Source: [13]

PHAST

The PHAST programme developed in Norway is used for analyses of toxic, fire and explosive hazards in industry, in use by more than 800 organisations worldwide. It is considered to be the most extensive available tool designated for modelling the consequences of a potential incident, from the initial release of substance to an analysis of dispersion over long distances, including modelling of the spread of a spill and its evaporation, as well as contamination of land by flammable and toxic substances, up to fires and explosions. It comprises an advanced data base of toxic, flammable and explosive substances (thermodynamic properties of more than 2500 chemical compounds).

The main advantages of the PHAST software is the credibility of results of conducted analyses and extensive possibilities of reporting in the form of complex reports and diagrams that facilitate the presentation of results (e.g. on location plans and diagrams of installations in the plant). The deployed mathematical models of physical phenomena are constantly being validated (with external experts for more than 30 years), verified and updated. This offers an extensive range of applications – modelling may comprise various types and sources of release, for example from cracks and leaks in pipelines, safety valves, cracks and jamming of tanks etc. Its interface is user friendly [14]. Fig. 5 presents events and diagrams devised in the PHAST software (the photograph shows the incident, and the diagram beside it presents results of modelling).

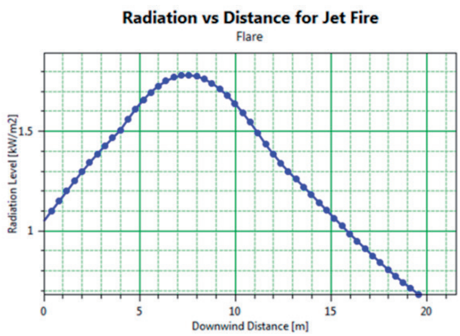
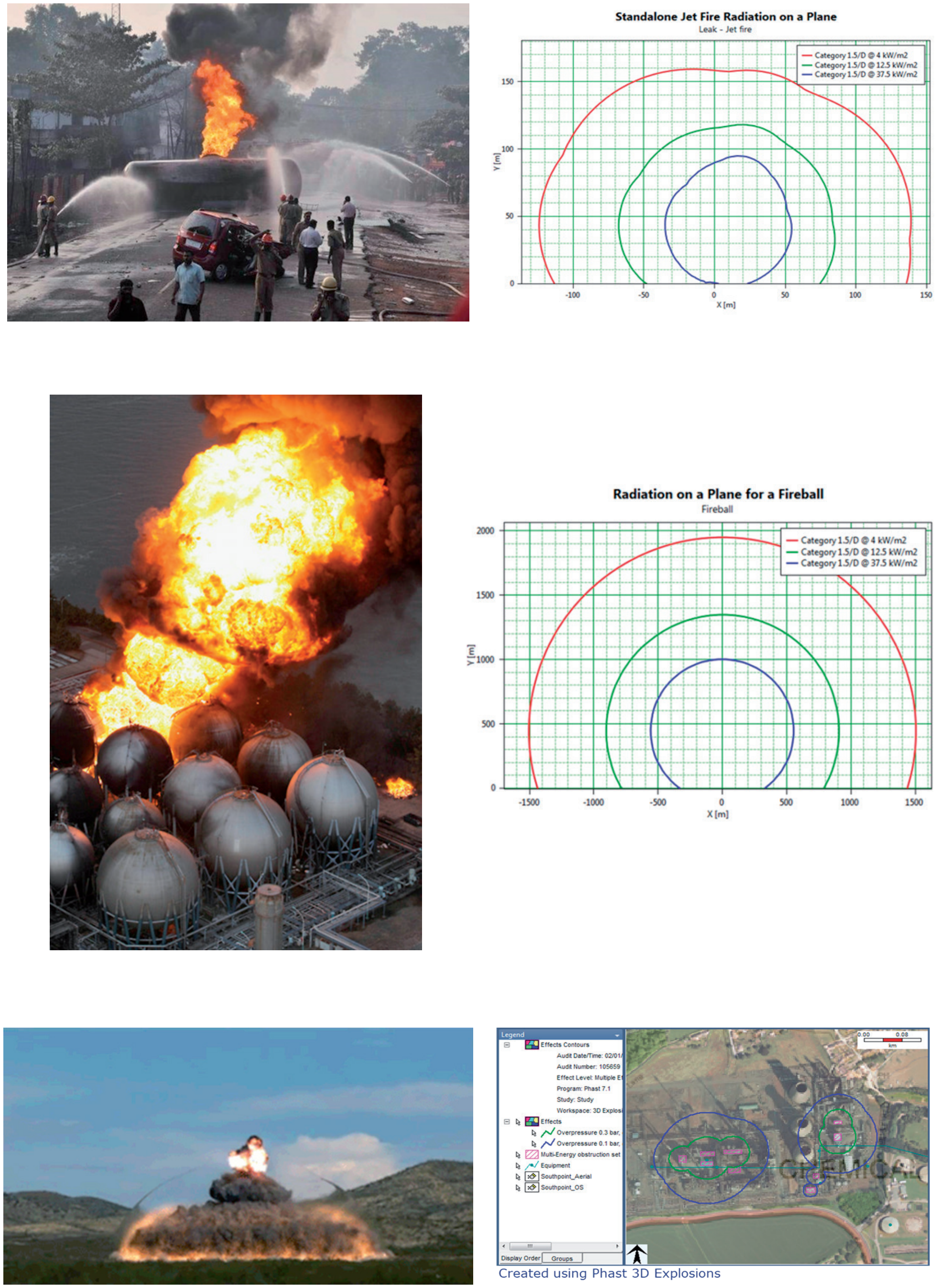


Fig. 5. Real incidents and results of calculations in the form of diagrams and visualisations of zone sizes in the PHAST software

Source: material obtained thanks to the curtesy of DNV GL – Digital Solutions



Continued Fig. 5.

SAFETI

The SAFETI programme is used for quantitative risk assessments in industrial facilities on the basis of entered data and the implementation of simulations of emergency scenarios. It allows graphical and textual visualisation of calculations of the territorial and individual risk, the determination of the possible number of victims or generation of FN curves.

It differs from the remaining programmes by the possibility of using transport of hazardous substances for the risk analysis. SAFETI assures a complex depiction of potential hazards along the entire route of the drive, which allows initial identification of high risk areas. The extensive possibilities offered by this software related to risk analysis connected with transport comprise:

- diverse transport means (road, rail, river, maritime transport, pipeline system etc.),
- option of defining alternative routes and types of substance release (leak, cracking of a tank etc.),
- consequences of an emergency are automatically appraised in specific places along the route (where the accident risk is the highest) or at even intervals, e.g. each 10 m,
- other factors that change along the route (population density, weather etc.), may also be defined and taken into consideration in the model.

Based on analyses of effects of an incident or failure in transport the route of passage or for a pipeline may be selected in a way assuring the minimising the consequences of a potential failure and their onerousness both for people and the natural environment (e.g. away from large settlements, rivers, water intakes etc.) [15]. Fig. 6 presents results generated with the use of SAFETI, which is a sub-programme of the PHAST application.

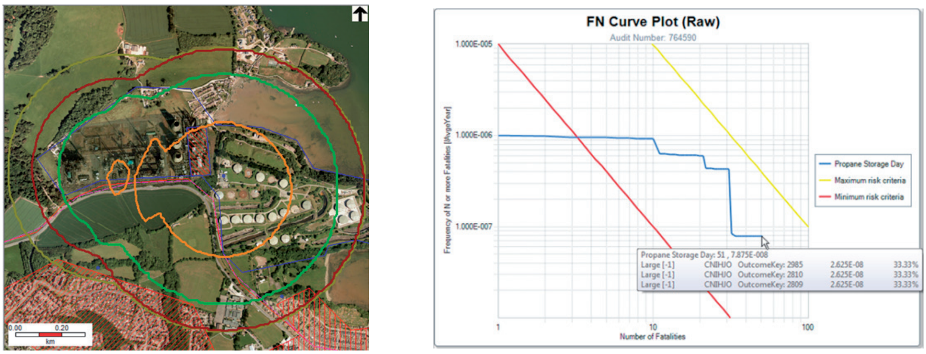


Fig. 6. Visualisation of the zone ranges and results of a risk analysis calculated in the SAFETI programme

Source: material gained thanks to the courtesy of DNV GL – Digital Solutions

RIZEX-2

The RIZEX-2 computational programme is an original product of Rizikon, a Ukrainian company. It comprises four major parts: graphical editor, computational module, results browser and a data base. The graphical editor enables the generation of vectoral and raster 2D and 3D maps and their bilateral transfer. Once the properties of facilities have been defined, the appropriate computational model should be selected. The computational level comprises the following sub-modules: fault tree, event tree, representative emergency incidents, release and evaporation of liquids, gas emission, dispersion (Gauss model and the model of gas heavier than air), formation of an explosive atmosphere, explosion (based on empirical models), fire (surface fire, jet fire, fireball, flash fire), 3D fire (taking into account effects of thermal radiation on the flame front), shrapnelling and risk estimation. It offers the possibility of generating standard "fault trees" and their saving in the database. They are presented in textual and graphical forms. The analysis of conditions giving rise to the emergency using the method of the "fault tree" adopting the "database" module enables searching for optimum solutions aimed at assuring an acceptable safety level. If costs borne for reducing the likelihood of occurrence of an emergency are high and unacceptable for a plant operator, the anticipated progression of the emergency is modelled and a review is made of appropriate solutions aimed at minimising the scale of fire consequences. The packet contains databases of substances and structural parameters of buildings and facilities, along with their resistance, for example to the overpressure wave. The structure of the packet and of files and databases allows unlimited development of computational models and information processing tools without impact on basic programme properties. The usage of "event tree" allows the execution of the effectiveness analysis of the applied protection means, assessment of the scale of development of various emergency scenarios and the determination of their likelihood. RIZEX-2 comprises models of the release of liquids and gases and their dispersion in the atmosphere. It allows modelling physical processes that take place during an emergency and a visualisation of results of conducted calculations.

As regards an explosive hazard, it takes into consideration vaporisation of overheated liquids including the specification of the progression rate of the process, as well as the generation of a combustive mixture with a concentration between the lower and upper exclusivity level. Its advantage is modelling various types of explosions, determination of the distribution and intensity of overpressure in space and estimating the likelihood of injuries caused to people and the destruction degree of diverse facilities. Effects of computational models describing explosions also comprise a graphical visualisation of the results of calculations and a printout of the textual report. On the other hand, computational models of shrapnelling offer the possibility of setting out its parameters during an explosion, delineating a hazardous zone for people and the likelihood of shrapnels hitting diverse facilities.

As regards fire hazards, it is possible to model fires and their consequences on the basis of experimental models and the determination of the level of risk of occurrence of injuries to people (various degrees of burns) and the capability of combustibles to ignite under the impact of thermal radiation. Calculations comprise the density of thermal fluxes caused by fires allowing for the effect of their attenuation by obstacles. This enables assessing the likely degree of burns in people present on escape routes. After entering data concerning the wind direction and speed and the likelihood of occurrence of risk in the progression of various scenarios for the occurrence and development of an emergency, risk contours are obtained.

The risk assessment performed in the RIZEX-2 programme allows graphic and textual visualisation of calculations of local and global risk, and importantly also the determination of the potential number of victims [16]. Illustrative results generated with the use of the RIZEX software have been shown on Fig. 7.

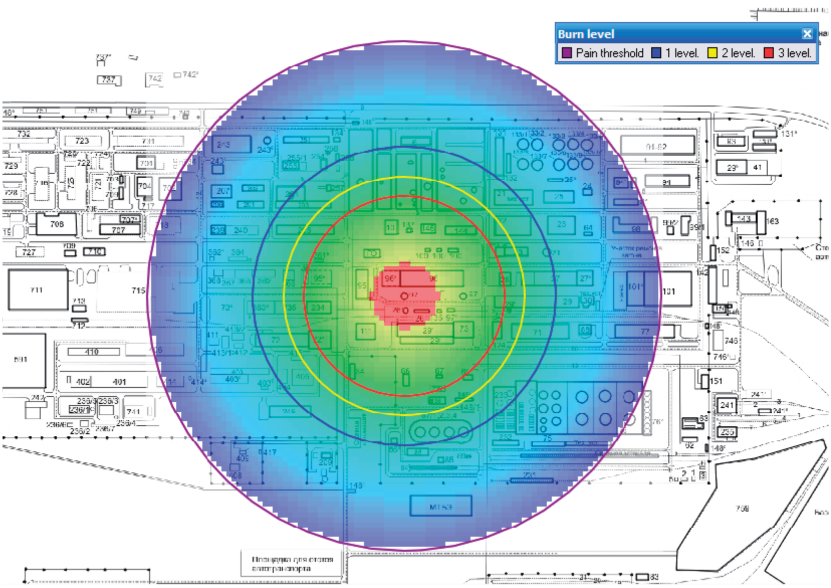


Fig. 7. Values of the density of heat stream in the function of distance from the fire source and borders of threats of various degrees of burns

Source: [16]

ALOHA

The ALOHA programme belonging to the CAMEO packet (*Computer-Aided Management of Emergency Operations*) is to be used for modelling the dispersion of gases and vapours of hazardous substances. It has been developed by the EPA (US Environmental Protection Agency), which as of 1970 has been implementing tasks aimed at protecting life, health and the environment. Results may be represented by visualising on plans of actual terrain in the MARPLOT®, ArcMap of Esri, Google Earth and Google maps. Red colour of the zone represents the highest hazard level, while orange and yellow – zones with its lower level.

Input data are entered by the user on his own or with the use of data transfer from weather measurement stations, which guarantees access to the most updated and verified information related to weather conditions. They have a considerable impact on results obtained in modelling the consequences of a release of hazardous substances. The results are presented in the form of figures, graphics (diagrams) or saved in a textual file. Visualisation of hazard zones takes place on digital maps and allows quick identification of the tactical intensions and the delineation of safe zones for assembly of forces and means and evacuation points.

Performance features of the programme and the appropriate research methodology have been verified in numerous research publications, and that guarantees the credibility of anticipated simulation results. Models of release source are correlated with dispersion models and apply both to single- and two-phase releases and temporary and continuous ones. As regards numerical analyses use is being made of Gauss and zone models.

The ALOHA programme contains a library with more than 60 substances and compounds, and offers a possibility of extending by own data. It allows the usage of the SI units. This in turn makes it possible to have the application used in a universal way as a tool for decision supporting in crisis situation or those with features of a crisis. Similarly as in the case of the remaining programmes, the precision of calculations depends on the quality of data entered to the programme by the user. A weakness of this tool is the lack of capacity of modelling certain types of releases. The accuracy of results obtained using the programme depends strictly on the wind velocity, variability of its direction, as well as the stability of atmospheric conditions.

Furthermore, ALOHA is not designated for needs of computations related to cases of fires and chemical reactions, solid particles suspended in gas (such as dispersion of a dust layer in air and its settling) and mixtures of substances [17]. Fig. 8 presents consequences of a fuel leak from a tank, and then the fire of a surface spill.

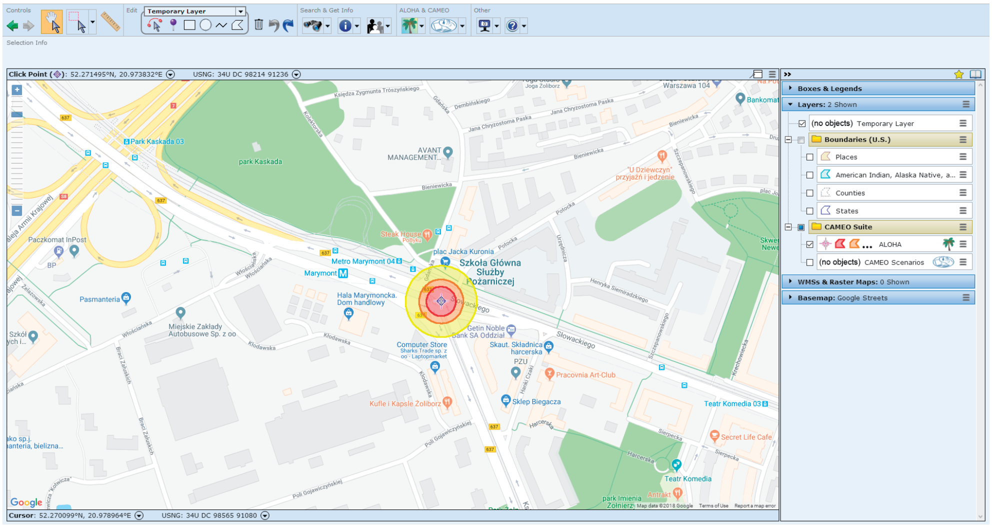


Fig. 8. Hazard zones calculated in the ALOHA programme applied to a Google map

Source: own study

ALOHA is a tool dedicated to specialists in the field of chemical and ecological rescuing, because it requires familiarity with processes that take place after the release of a hazardous substance to the environment. Furthermore, automatic verification of the selection of simulation model is also conducted. The strength of this programme is the fact that this software is free of charge and generally accessible, operating in the Windows and Mac environment and is constantly being upgraded.

A specification of the basic characteristic features of software dedicate to modelling consequences of industrial failures has been presented in table 1.

Table 1. Specification of functions most frequently applied in programmes for modelling consequences of industrial failures

Programme	BREEZE CHARM	EFFECTS	PHAST/ SAFETI	ALOHA	RIZEX
1. Free of charge	NO	NO	NO	YES	NO
2. User friendly	YES	YES	YES	YES	YES
3. Requires advanced knowl-edge of a risk analyst	YES	YES	YES	NO	NO

Continued Table 1.

Programme	BREEZE CHARM	EFFECTS	PHAST/ SAFETI	ALOHA	RIZEX
4. in Polish	NO	NO	NO	NO	NO
5. Updated programme, models continuously verified	NO	YES	YES	NO	NO
6. Incorporated models					
Dispersion model of light gas	YES	YES	YES	YES	YES
Dispersion model of heavy gas	YES	YES	YES	YES	YES
Universal dispersion model	YES	YES	YES	NO	YES
Model of surface fire	YES	YES	YES	YES	YES
Model of jet fire	YES	YES	YES	YES	YES
Model of flash fire	YES	YES	YES	YES	YES
Model of fireball	YES	YES	YES	NO	YES
Model of explosion in unconfined space	YES	YES	YES	YES	YES
BLEVE explosion model	YES	YES	YES	YES	YES
Quantitative risk assessment (individual risk, group risk, societal risk)	YES	YES	YES (SAFETI)	-	YES
7. Allowing for field obstacles and the impact of land relief on the course of the explosion	NO	NO	YES (PHAST 3D)	NO	NO
8. Modelling of explosion inside a building	NO	NO	NO	NO	NO

Continued Table 1.

Programme	BREEZE CHARM	EFFECTS	PHAST/ SAFETI	ALOHA	RIZEX
9. Modelling of shrapnelling during an explosion	NO	NO	NO	NO	YES
10. Modelling dust explosions	NO	NO	NO	NO	NO
11. Domino effect	NO	NO	YES	NO	NO
12. Verification of obtained results by researchers	YES	YES	YES	YES	YES
13. Presentation of results in a graphical and tabular form	YES	YES	YES	YES	YES
14. Deployed GIS module	YES	YES	YES	YES	YES

Source: own study

Recently in various research centres worldwide diverse models of computational fluid mechanics have been devised and are still being developed, such as: FLACS, PHOENICS, FLUENT, JASMINE, ANSYNS, FDS, Kameleon FireEx (KFX) used to describe the fire environment, dispersion and explosions. Their advantage is the possibility of making simulations of physical phenomena in conditions that are either impossible or difficult to achieve in reality. Nevertheless it should be borne in mind that the CFD models have unfortunately certain inherent drawbacks, such as for example the necessity of validating the modelling, possibility of making an error while defining the computational model (e.g. border conditions, selection of the computational grid), as well as broad knowledge in the field of liquid mechanics, heat transport, chemistry of combustion processes, dynamics of fires and other associated disciplines.

3. Recapitulation

The selection of a computer programme meant to assist the implementation of particular stages of the process that comprises risk analysis and assessment for lower-tier and upper-tier establishments determines the credibility of final results. Despite easy handling of the programmes, they require that the person making use of such a programme needs to have completed the required training courses, must have experience and knowledge related to safety. As regards calculation of physical effects and consequences of emergency releases of hazardous substances due to diverse process failures, it is considered that from among the programmes specified in the article the PHAST and the EFFECTS programmes are considered to be the best given their accessibility, credibility of gained results and functionality. Only a few institutions in Poland have them at disposal. What is more, their application requires intense training with respect to theory and practice in the scope of analyses of process risk, and as an effect the obtained results of calculations without having such knowledge is impossible. As a rule costs of the software are quite high. Their certain deficiency is lack of possibility of defining parameters of shrapnelling during explosion and the likelihood of the shrapnels hitting facilities exposed to their direct impact. This function is offered by the RIZEX programme. The application of the appropriate computer programme allows designing adequate protection and safety means needed in the event of occurrence of a failure. The obtained results assist the process of spatial development with respect to allocation of low-tier or high-tier establishments, new projects and distribution of public space areas and residential housing zones in the vicinity of industrial plants.

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