Chapter

Risk Management in the Area of Major Industrial Accident Prevention in the EU and Slovak Republic

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Abstract

The SEVESO II and III Directives relate to approximately 12,000 EU establishments working with the hazardous substances. The majority of EU member states implement new requirements of the SEVESO III Directive to their legal environment. The third revision goes hand in hand with the enforcement of the CLP legislation, concerning the Classification, Labelling and Packaging of chemical substances and mixtures. Risk Management is appearing as one of the most important challenges nowadays to raise the prevention level in these establishments. The book chapter analyses the industrial accidents and identified consequences and impacts whose results can be implemented to the effective prevention. The benefit of this chapter is the summarisation of the legal regulations, information systems and especially the statistics of the industrial accidents in Slovakia and the EU. The risk assessment is one of the problem areas of prevention therefore, it was necessary to present the methods and techniques utilised here and to clarify the approach used in the Slovak Republic. The programme ALOHA is most frequently used for modelling the consequences and therefore we presented its possible utilisation on a particular example at the end of this article. The main goal of this chapter is to show how is important to proceed risk management in establishments with hazardous substances is, what kind of methods should be use here to decrease risks and possibilities for modelling its impacts.

Keywords: risk management, industrial accidents, prevention, Seveso, Slovakia, modelling

1. Introduction

The major industrial accidents are phenomena whose effects threaten the human lives, property and environment. The EU decided to solve this problem in 1982 through the legal tool known as SEVESO I that has been amended three times so far. Currently the SEVESO III Directive is valid and in 2015 Slovakia issued a law about the major industrial accident prevention as amended. These legal regulations determine the rules for handling with hazardous substances and fulfilling procedures connected with their handling procedures in the companies exceeding the amounts defined by the law. The transposition of the new SEVESO III Directive has created the necessary space for modifying the problem areas – also the risk management of the industrial processes.

The major industrial accident (MIA) prevention is a specific topic for preventing, planning and solving the crisis phenomena not only in Slovakia but also on the international level. In spite of the fact that in most EU countries, in the years 2008–2018 there was a decrease in the number of people injured in accidents at work and in fatal accidents in industrial processes, it is necessary to pay attention to this area [1, 2].

The risk management that consists of the risk assessment and risk treatment is one of the most important pillars of preventing the accident development [3]. The great amount of approaches, methods and techniques in this area make it often chaotic, however, the most substantial assumption is to understand the philosophy of assessing and managing the risks the how to implement it. The calculation mechanisms and formulae serve only as an aid for defining the risk and determining its acceptability or unacceptability. The objective of this chapter was the clarification of the procedures that will be understandable and usable [4–6].

This chapter deals with MIA prevention concerning only the SEVESO III companies. The under-threshold establishments are not taken into account.

The following information was taken into consideration for analysing the accidents:

- The number of injured/dead people and damages of the property,

- The accident during the validity of the SEVESO I, II and III.

The data collection process also utilised the semi-structured interviews with the employees of the Ministry of Environment of the Slovak Republic and the Slovak Environment Agency. The databases collecting the data about the MIAs according to the classification life/health, property and environment were analysed for identifying the causes and effects.

In the framework of the case study, we utilised the on-site observations and subsequently the software for simulating the consequences and impacts.

2. Industrial accident prevention

The constant increasing of the technological progress brings also development of the industrial accidents more and more frequently. The industrial accidents belong to the anthropogenic phenomena whose occurrence can be determined with a certain probability. The need of its legal adaptation became inevitable in the 1980s.

Bahr says that the accident is an unplanned development of events that lead to undesirable injuries, losses of lives, to damaging the property and environment. He also declares that it is necessary to differentiate the so called near-miss – the nuclear accident Three Mile Island can serve here as an example. During this crisis phenomenon not that big amount of radioactivity penetrated to the environment that would have threatened the lives of the citizens, however, the investigation showed a lot of shortages that drew lessons from this near-miss [7].

Marvin Rausand says that during the recent decades a lot of large accidents have drawn attention of the general public to the need of increasing the awareness about the risks that are connected with the technological systems and activities. The industrial accidents also affected the stance of the competent authorities concerning the safety in this area. The companies themselves are also aware of the need of implementing the principles of an effective prevention in the enterprises especially in connection with the high financial costs and losses of lives in the case an accident develops. The **Table 1** brings examples of major accidents with hazardous substances (HS) [8].

In spite of the negative effects and impacts, these accidents give us precious information for improving the prevention effectiveness in this area.

The overview in the **Table 1** was created from a file including the accidents and it should serve as a reminder that safety must never be on the second place and also the risks with a low probability bring frequently serious impacts. Macza analyses some of these accidents and the responses and perception of the society to each of them in connection with the changes of the legal regulations and other interactions [11].

In the further text we will deal only with accidents in the chemical enterprises that utilise hazardous substances in their processes.

Ostrom says in his book that several types of the primary and secondary crisis phenomena can develop in the industrial operations working with hazardous substances. They can cause an accident with the following consequence:

- the leakage of a hazardous substance outside the plant (small or large),
- the leakage of a hazardous substance in the plant (small or large),
- the fire or explosion (small or large),
- the injuries of the employees (acute, chronic),
- the traffic accident in the company,
- the terrorist activity,
- the secondary ones (e.g. damaging the company's reputation) [12].

The industrial accidents are connected especially with the uncontrolled leakage and spreading the hazardous substances that threat the life and health of people, damage the property and pollute the environment [13]. The hazardous substances causing the industrial accidents are of the chemical or radioactive origin and can come either from disrupting the stability of the stationary source of the hazardous substance (production of the equipment, warehouses, equipment using the hazardous substance in the process) or the mobile sources (cars or railway carriages determined for transporting the hazardous substances) [14].

In the EU framework there are different legal regulations for the nuclear and chemical premises that are subsequently transposed to the legal system of the member states. Just the development of the industrial accidents and investigating their causes aroused the efforts to adapt the given area through the legal regulations and thorough inspection in this field (see the **Table 2**).

The aforementioned accidents were the principal milestones for creating the safety standards of the industrial processes and application of the changes in the SEVESO Directive framework.

2.1 Industrial accident prevention

2.1.1 Prevention of major industrial accidents in the EU

2.1.1.1 The legal environment in the area of prevention of major industrial accidents in the EU

The afore-mentioned industrial accidents as well as a whole range of others showed the failure of the technology and operators that caused the death of a lot of

Place of the accident	Year	Effects	Impacts
Seveso, Italy	1976	Leakage of dioxin to atmosphere	2,000 poisoned people, environment pollution, mass evacuation
The North Sea, Norway	1977	Leakage of crude oil from oil platform	Significant sea pollution
Three Mile Island, USA	1979	Near-miss, a potential for leaking a larger amount of radioactivity	Without any serious impacts
Bhopal, India	1984	Leakage of toxic methyl isocyanate	3,800 dead people, 20,000 injured people, 200,000 evacuated people
Mexico City, Mexico	1984	Explosion and fire of LPG container with subsequent pressure wave,	500 dead people, material damages
Basel, Switzerland	1986	Leakage of chemicals from the Sandoz plant to the Rhein river	River contamination, serious environmental damage, cross-border impacts
Zeebrugge, Belgium	1987	Accident of the British tanker Herald of Free Enterprise	209 dead people, material damages
The North Sea, UK	1988	Explosion and fire on the oil platform "Piper Alpha"	167 dead people, extensive damage
Pasadena, USA	1989	Explosion and fire with subsequent pressure wave and heat radiation	23 dead and 100 injured people
The Baltic Sea	1994	Overturning the ferry Estonia	853 dead people, serious environmental damage
Longford, Australia	1998	Explosion and fire with subsequent pressure wave and heat radiation	2 dead people, Melbourne without gas for 19days
Brittany, France	1999	Sinking the tanker Erika with extensive leakage of HS to the sea	Extensive leakage of oil substances to the sea and its pollution
Enschede, the Netherlands	2000	Explosion and pressure wave in the company for pyrotechnic production	22 dead people, 1,000 injured people, more than 300 destroyed houses
Toulouse, France	2001	Explosion and fire with subsequent pressure wave and heat radiation	30 people dead, 2,000 injured people, 600 destroyed houses
Galicia, Spain	2002	Sinking the tanker Prestige with extensive leakage of HS to the sea	Extensive leakage of oil substances to the sea and its pollution
Texas, USA	2005	Explosion and fire with subsequent pressure wave and heat radiation	15 dead people, 180 injured people
Hertfordshire, Great Britain	2005	Explosion and fire with subsequent pressure wave and heat radiation	43 injured people, extensive damage
Gulf of Mexico	2010	Explosion of the oil rig Deepwater Horizon	11 dead people, 17 injured people, destroyed equipment, leakage of oil slick to the sea
Great Britain	2013	Explosions and a fire on a slab casting machine in a steel works	Damage to property more than 2 mil.Euros, 12 injuries

Place of the accident	Year	Effects	Impacts
Germany, Eltmann plant	2017	Explosion resulting in fire in a rolling element manufacturing plant	1 dead, 3 critically injured, 21 at risk, 150 000 Euros damage.
Spain	2020	Ammonia release in chemical establishment (upper tier)	the death of a worker, another one was critically injured, 15 workers were mildly injured

Table 1.
The most famous industrial accidents worldwide – An overview [9, 10].

people or the accident effects caused them durable consequences for their health and losses of the material values and the environment that can be of a long-term character but also irreversible. Therefore the number one issue is the prevention of such events and the implementation of the preventive measures in the industrial environment. The EU tries to regulate this environment and to determine the rules for the companies that are the most dangerous ones from the point of view of the hazardous substances concentration. The SEVESO Directive is such a tool – it has been amended several times and currently the SEVESO III Directive is valid.

The SEVESO III Directive creates the basic framework dealing with the prevention of and preparedness for overcoming the major industrial accidents of hazardous substances. Due to the rapid technological development and globalisation the updating process of this directive is under way in certain time intervals – from the SEVESO I to SEVESO III Directives. The overview of the most important updating of this directive is as follows:

- Council Directive 82/501/EEC of 24 June 1982 on the major-accident hazards of certain industrial activities (known as SEVESO I Directive),
- Council Directive 96/82/EC of 9 December 1996 on the control of major-accident hazards involving dangerous substances (known as SEVESO II Directive). This directive that became effective on 3rd February 1997 cancelled the SEVESO I Directive,
- 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, amending and subsequently repealing Council Directive 96/82/EC.

2.1.1.2 The competent bodies responsible for the legislative processes and control of the industrial enterprises in the EU

The unified implementation and thorough fulfilment of the SEVESO III Directive provisions in the whole EU requires a close collaboration between the corresponding bodies of all member states and the European Commission. The competent bodies responsible for the major industrial accident prevention in the EU are:

- The competent institutions in the area of the major industrial accident prevention (CCA)
- The UN agency – the environmental section (UNEP)
- The UN economic commission (UNECE)
- The office for major industrial accidents (MAHB)

2.1.1.3 The information systems of industrial accidents in the EU

The information systems of the industrial accidents are a useful tool for supporting the decision-making process of prevention and also the solution of the major industrial accident prevention. Currently these information systems contain databases that concentrate data about the emergencies and participate in preventing

Accident	Accident cause	Accident consequences	Measures
Bhopal (1984) Union Carbide for production of the insecticide SEVIN	• Water penetrated the container of methyl isocyanate with subsequent exothermal reaction, • storing hazardous substances in large containers instead of in small barrels.	• Leakage of 20–30 tons of methyl isocyanate, • 3,787 victims, • deaths of the farm animals, • damages approximately 20 billion USD, • the surroundings contaminated even today.	• Increasing requirements on safety of the operation in the developing countries (by the multinationals), • improving the citizen protection against the effects of the hazardous substances.
Seveso (1976) Chemical plant ICMESA	• Increased temperature in the boiler and subsequent chemical reaction with leakage of poisonous gas (cloud) to the atmosphere.	• 37,000 people exposed to the toxic cloud, • Death of 3,300 animals and later deaths of 78,000 animals, • The decontamination price - 32 billion USD.	• Adopting the SEVESO Directive that is valid (with certain limitations) also today.
Baia Mare (2000) Golden Mine Aurul	• Building a barrier from insufficiently tough material, • long-lasting strong rains – destabilisation of the barrier, • leakage of mercury to the air during gold separation, • combination of highly dangerous manufacturing procedures with insufficient safety provisions for technological procedures.	• Contamination of the rivers Sasal, Tisa and Danube, • mass fish kill, deaths of other organisms in these rivers, • a cross-border accident, Hungary required a financial compensation.	• Amendment of the SEVESO II Directive (including the ecological accidents to major industrial accidents), • exempting selected activities from the Mining Act and moving them under the SEVESO II Directive, • increasing the safety measures in this area.
Buncefield (2005) oils warehouse terminal	• Failure of level gauge that indicated an incorrect petrol level, • failures of other technical barriers and warning devices.	• Injuries of more than 40 people, • enormous damages of the company property and in the surroundings.	• Thorough and quality assessment and risk management with an emphasis on analysing the influence of the human factor, • integrating other protection elements for limiting the accident (detectors and cameras), • good safety culture and employees´ motivation.

Table 2.
Causes and consequences of selected industrial accidents [15, 16].

similar crisis phenomena. The Major Accident Hazards Bureau (MAHB) ensures the summarisation of the data form analysing the major industrial accidents in the EU. The MAHB provides the basic research and scientific support to the EU in the area of formulating, realising and monitoring the EU policies with the goal to check the risks of developing major industrial accidents.

The industrial accidents are gathered in the national and multinational databases. The most useful databases concentrating the data about the accidents are:

- MARS (Major Accidents Reporting System) [15].
- SPIRS (Seveso Plants Information Retrieval System) [17].
- ARIA (Analyse, Recherche et Information sur les Accidents) [16].
- FACTS (Failure and Accidents Technical Information System) [18].
- ZEMA (Enterprise Data Management) [19].

The MARS database collects data about the major industrial accidents and near misses in the SEVESO III companies in the EU. The purpose of the database is to provide data for the statistic assessment with the goal to avoid development of such events and it also serves as a source of lessons from the accidents. Based on the in advance defined rules of the responsible institutions in the EU the EU member states provide information about the major industrial accidents and near-misses to the Joint Research Centre of EC in Ispra through the electronic database MARS. The report of the event to the MARS database is obligatory for the EU member states in the case of an event that fulfils the criteria of a major industrial accident presented in the Appendix IV of the SEVESO III Directive.

The MARS database can be utilised by the bodies of the state administration of the EU member states, the industrial and trade associations, Trade Unions, etc. Currently there is at disposal also the interactive version of the database, the so-called eMARS version that is available at the internet.

	Type of Accident			
Year	**Major Accident**	**Near Miss**	**Other Event**	**Total**
2010	30	7	1	38
2011	22	0	3	25
2012	28	9	5	42
2013	21	7	5	33
2014	23	2	0	25
2015	22	4	2	28
2016	13	3	1	17
2017	12	1	1	14
2018	11	2	3	16
2019	1	0	1	2
Total	183	35	22	240

Table 3.
Contingency table of accidents according to type and year [15].

The **Table 3** brings the classification according to the types of the accident and the year when the given type of accident developed during 2010–2019. As we can see the largest amount of the most serious accidents developed in 2010–2030 accidents. The lowest number of the major accidents was registered in 2019 – only one accident. However, during the last three years, not all accidents have been recorded and therefore the amount of the accidents can increase. The near-miss is another type of the accident. The highest number of the near misses was in 2012–9 accidents. The lowest amount of the near misses is registered in 2011 and 2019–0. However, the number can be changed in 2019 – similarly as in the case of the major accident. The last accident type is the so called another event. The highest number is recorded in the years 2012 and 2013–5, on the other hand there was none in 2014. In 2012 we registered the highest amount of all the aforementioned types – 42 accidents, on the contrary the lowest amount was in 2019 – only two of them. Also in the case of the year 2019, the number of the accidents can be changed due to registering other accidents.

Another directive directly connected with the SEVESO III Directive is the SPIRS database (SEVESO Plants Information Retrieval System). This database gathers especially the data identifying the SEVESO establishments (their name, address, location in the framework of the country's territory, hazardous substances in the company and their volume, number of employees, number of citizens in the circle of 5 and 10 kilometres, the distance from the nearest water course, the company activity, etc.).

There are several other databases worldwide gathering the data about the industrial accidents. One of them is also the ARIA database formed by the Bureau for Analysis of Industrial Risks and Pollutions (BARPI) in 1992 by the French Ministry of Ecology, Sustainable Development and Energy [16].

The database FACTS is a functional one in the Netherlands and includes data about more than 23,000 industrial accidents with hazardous substances globally during the recent 90 years. It contains not only the accidents that happened but also the near-misses from the point of view of their seriousness and consequences. The most serious ones are processed in the form of reports that are available and provide a data flow for assessing the risk and preventing the failures [18].

Germany has a database for the industrial accidents called ZEMA. It comprises data about small accidents but also about serious ones affecting seriously the population, environment and property [20].

2.1.1.4 Major industrial accident prevention in the Slovak Republic

The Slovak Republic is a small country; however, the industrial accidents occurred also in its territory. The legal framework for the major industrial accidents in the SEVESO III context began to be solved after the Slovak Republic had entered the EU in 2004. In Slovakia, there are about 80 SEVESO establishment and they are divided to the categories A and B [21]. Their number can be changed due to re-categorising of the companies.

The legal regulations controlling the area of protection against the consequences of industrial accidents have an important place in the Slovak legal system. Their goal is to protect people, the environment and material values against the negative impacts of the industrial accidents but also other crisis phenomena connected with leaking hazardous substances to the air, soil or water.

The Ministry of Environment of the Slovak Republic is responsible for the preparation of the legal regulations in the area of preventing and removing the consequences of the industrial accidents, however, partial tasks in this area are also fulfilled by the Ministry of Interior of the Slovak Republic or the Ministry of Economy of the Slovak Republic. Besides the legal regulations that are generally obligatory, there are also technical standards that are only recommended.

The following legal regulations solve the area of the major industrial accident prevention:

- the law No. 128/2015 Coll. about major industrial accident prevention as amended and the implementing regulations that complete this law (further the law about the Major industrial accidents (MIA) prevention),

- the decree of the Ministry of Environment of the Slovak Republic No. 198/2015 Coll. that realises some provisions of the law No. 128/2015 about major industrial accident prevention as amended.

There are several subjects in the area of the MIA prevention that are mutually interactive:

- State administration in the MIA prevention area,

- SEVESO establishments,

- Evaluators [21].

In the further text, we will characterise the individual competencies of all represented subjects that participate in the major industrial prevention in practice.

The most intensive collaboration takes place between the Ministry of Environment of the Slovak Republic, Slovak Agency of Environment and district offices in the seat of the regions.

According to the law about MIA prevention the companies are divided into two categories – the A category (the upper tier) And B category (the lower tier). The number is equal, it can change regarding to the re-categorisation of the companies from the A to the B group or including a new enterprise under the law about MIA prevention. The companies differ from each other especially in the area of the defined obligations that have to be fulfilled and the categorisation itself is realised according to the total number of the hazardous substances in the enterprise (according to the Appendix 1 in the law of MIA prevention) [21].

The threshold quantities defined in the tables in the first and second part of the law about MIA prevention relate to each enterprise. The quantities that are to be taken into account are the maximal amounts that are present or can probably be present at any moment. The hazardous substances present in the company amounting 2% or less than 2% of the corresponding threshold quantity are not taken into consideration for calculating the total present volume if their location in the company cannot cause any major industrial accident in another part of the enterprise [21].

If the company has no hazardous substance in an amount that is greater or equals the corresponding threshold quantity the following rule for defining the fact whether the company is under the law about MIA prevention is used.

The law relates to the companies of the B category, if the sum:

$$N = \frac{q_1}{Q_{B1}} + \frac{q_2}{Q_{B2}} + \frac{q_3}{Q_{B3}} + \frac{q_4}{Q_{B3}} + \frac{q_5}{Q_{B5}} + \ldots + \frac{q_x}{Q_{BX}} \geq 1 \qquad (1)$$

N = is the sum of the relative quantities of two or several hazardous substances present in the company,

qx = is the amount of the hazardous substance x (or the present hazardous substances of the same class/category) according to the part 1 or 2,

QBX = is the corresponding threshold quantity for the hazardous substances or the class/category "x" from the column 3 – part 1 or from the column 3 – part 2.

The law relates to the companies of the B category, if the sum:

$$N = \frac{q_1}{Q_{A1}} + \frac{q_2}{Q_{A2}} + \frac{q_3}{Q_{A3}} + \frac{q_4}{Q_{A4}} + \frac{q_5}{Q_{A5}} + \ldots + \frac{q_x}{Q_{AX}} \geq 1 \quad (2)$$

N = is the sum of the relative quantities of two or several hazardous substances present in the company,

qx = is the amount of the hazardous substance x (or the present hazardous substances of the same class/category) according to the part 1 or 2,

QAX = is the corresponding threshold quantity for the hazardous substance or the class/category "x" from the column 2 – part 1 or from the column 2 – part 2 [21].

2.1.1.5 Information systems of the industrial accidents in Slovakia

Currently there are two information systems serving for registering the industrial accidents in Slovakia – the Information System of MIA Prevention and the Information System of the Industrial Accidents. Both information systems serve for gathering, recording, listing, searching, utilising, saving and transferring information about the industrial accidents in Slovakia [14].

3. Risk management of the industrial processes

The risk assessment and risk management are problematic areas in the area of the MIA prevention. The existence of a whole range of the systematic procedures, methods, techniques and software means increases the uncertainty rate for comparing the results of various companies in the framework of processing the safety documentation. Therefore the scientific and research activities in this area should bring new knowledge and approaches that will bring optimal solutions.

3.1 Position and importance of the risk management in the area of MIA prevention

The risk assessment and management is an interdisciplinary filed that is used in a lot of areas of the social life. Every company has to fulfil both the strategic and operational objectives in the individual sectors of its activity. The manufacturing process management, HR, management of the financial processes, quality and safety and a whole range of others belong here. The safety management as one of the non-profit company activities seems to be superfluous if there are no crisis phenomena until anything happens. The safety management is realised with an emphasis on the area of Safety and Protection of Health at Work, on the environment but also the accident prevention if we work with the hazardous substances in our processes. The risk assessment and management is the basis for implementing the preventive measures and reducing the risk of developing the crisis phenomena.

The risk assessment and management is of the key importance from the point of view of minimising the damages and losses of our interests. The protection of life, property and environment cannot be ensured without identifying the risk sources, their analysis and assessment from the point of view of undesirable effects of the hazardous substance.

3.2 Approaches and systematic procedures of the risk assessment utilised in the companies

In general we can say that the risk management process consisting of assessing and managing the risks can be implemented in every area of the social life. The unbinding standards in the form of the ISO standards are transposed to the legal standards of several countries worldwide. ISO 31 000 Risk Management was issued in 2019 and was implemented to the individual EU member states. This process can be implemented for the whole organisation and all processes that are realised in its framework. Sometimes the organisations evaluate and manage the risks only up to a certain level. This standard defines several principles that are to be fulfilled for the process to be effective. Its main aim is the development, implementation and continual improvement of the framework whose purpose is to integrate the risk management process to the company management, to its strategy and planning processes, management and also to the process of reporting, policies and other activities.

According to STN ISO 31 000, the risk management process represents a systematic implementation of the policies, procedures and implementation of practice for these specific activities (see the **Figure 1**) [23].

The **Figure 1** depicts the overall risk management process. In practice the organisations manage the risks through identifying, analysing and assessing them and subsequently they evaluate which means to use to reduce the unacceptable risks to an acceptable level. During the whole process they communicate and consult with the interested parties and monitor the risks and then the measures that were implemented. The standard used the term risk treatment; however, the MIA prevention area uses the term risk management.

The risk management of the industrial processes is realised especially in connection with fulfilling the legal requirements. The most frequent reason for its realisation is the employees' protection in the framework of the safety and protection of health at work. It is more complicated to assess and manage the risks in the case of

Figure 1.
Risk management process [23].

the accident development prevention, especially in those conditions that have to fulfil the requirements of the law about MIA prevention.

The risk assessment process in the industrial enterprises (according to the law about MIA prevention) consists of:

- identifying the dangers (risk sources) and events that can arouse a major industrial accident,
- quantifying the probability or frequency of the MIA development,
- estimating the extent and seriousness of the consequences on the MIA for people's health, environment and property, assessing the risk and evaluating the risk acceptability [21].

The risk assessment as an independent phase is part of the operator's documentation in compliance with the law and therefore it is important for the company representatives to understand this process and to be able to realise it appropriately. The risk assessment and management can be realised by a whole range of approaches, however, the idea algorithm has certain parallels. The logic of the overall procedure is the same almost in any environment; it is different only in the points that are specific for the given area. If the person (expert) that carries it out will understand its essence and usability, he/she is able to implement this process and to choose the optimal methods and techniques of the individual steps of this approach.

The following items can be utilised for the risk assessment:

- the systematic procedure,
- the method or a set of techniques,
- the mathematical calculation.

3.2.1 Systematic procedures for the risk assessment

The systematic procedures are complex algorithms that utilise the methods, techniques and mathematical formulae in the individual steps. The most frequently used are:

- PRA,
- CPQRA,
- ARAMIS [22–27].

3.3 Assessing the MIA prevention in the conditions of Slovakia and shortages detected

There are several problems that create a space for the scientific and research activity in the area of the MIA prevention. The improvement of the safety level of the SEVESO establishments in Slovakia by creating a complex model of the risk assessment of the industrial processes using the quantitative methods, with its harmonisation with the EU standards and subsequent implementation in the Slovak conditions has been the basic aim of the scientific and research activity at the FSE UNIZA during the recent years.

Based on the currently valid documents and approaches that are utilised in practice the risk management can be divided into two basic phases as follows:

- the risk assessment,
- the risk treatment.

These both phases of the risk management are in the mutual interaction. From the point of view of the sequence the risk assessment has to be realised first, then it is necessary to reduce the unacceptable risks and subsequently to monitor the reduced risks and all of that represents their treatment/management.

The risk assessment can be characterised as a systematic activity of an individual or a group of people (experts) whose main goal is to state the acceptability or unacceptability of the risks on the basis of criteria defined in advance. From the functional viewpoint we divide the risk assessment process to two phases:

- the preparatory phase,
- the realisation phase.

The preparatory phase of the risk assessment has a character of realising the decisions and preparatory activities connected with this phase whose selected outputs are connected with the individual steps of the realisation phase of the risk assessment. The realisation phase of the risk assessment is an implementation activity into which the data from the preparatory phase enter and then we implement the selected procedures, methods and techniques in the individual steps by the working group (evaluators) for assessing the risks of a particular process. A list of the acceptable and unacceptable risks that are subsequently reduced and as the residual risks they enter the process of monitoring the risk is created. Every phase has its steps that are logically interconnected. The **Figure 2** depicts the whole risk assessment process.

The quality of the preparatory phase is closely connected with the quality of the outputs that are obtained at the end of the realisation phase. It depends especially on the professionalism and assumptions of the human factor (working group) that participates both in making decisions in individual phases or steps and realising the analysis itself (expert evaluation) of the given system. The human factor is also connected with the rate of uncertainty that enters the process and can affect the analysis results and cause deviations. The highest rate of uncertainty influences the results in the risk assessment phase due to the calculations that are part of the implemented methods. These deviations are connected with the rate of knowledge of the evaluators and the information that is available at the time of the analysis.

The complex model was one of the main outputs of the FSE UNIZA's research activity. It was created on the basis of several sequential steps using methods, approaches and tools from other projects solved at our faculty. During its creation it was necessary to define the main risk management phases of the complex model (the risk assessment and management) and then to determine the individual steps. The solution process was aimed at the risk assessment phase that was then analysed and developed. The existing systematic procedures, methods and techniques for the risk assessment in the industrial environment of the Slovak Republic and worldwide were evaluated for the necessary identification, analysis and assessment of the risk.

Based on several assessment criteria we chose some parts and calculations of the systematic approach ARAMIS, QRA method, Boolean algebra, failure tree, event tree, etc. We utilised also the results of the tasks solved in the project framework for defining the input and output parameters of the model:

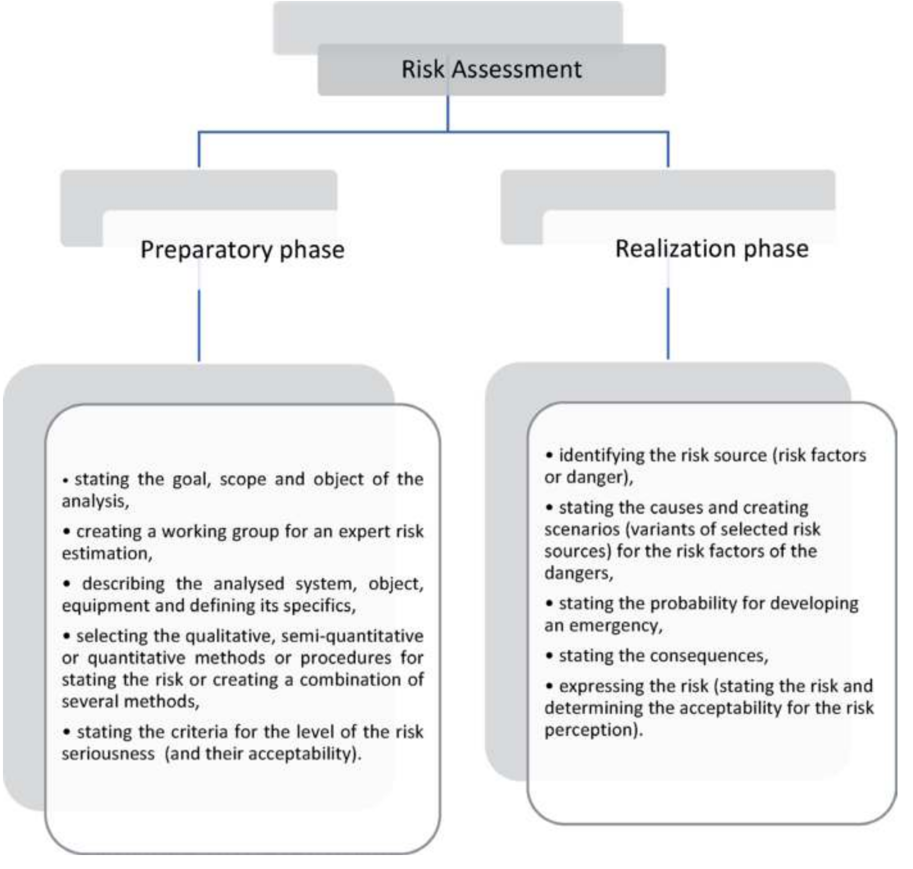

Figure 2.
Basic phases and steps of the risk assessment.

- analysing and synthesising the conclusions of the research of the SEVESO establishments in the form of the research report – Statistical Research of SEVESO Establishments.

- the working meetings.

We selected the methods and calculation mechanisms that were then implemented in the model. The project team's key procedure was the ARAMIS method that consists of two key methods – the Methodology for the Identification of Major Accident Hazards (MIMA) that identifies the risk sources of the major accidents and defines the highest risk potential of the equipment. The second method is called the Methodology for the Identification of Reference Accident Scenarios (MIRAS) that is a methodology for identifying the safety measures and procedures for scenarios identified by MIMAH.

The output of the whole analysis is the determination of the risk, designing suitable measures followed by an investment or organisational aim in the area of improving the operation safety.

4. Modelling the effects and impacts of the accidents

The current software tools used for modelling the effects and impacts are on a very good level. Their main task is to simulate (based on the models) the formation and development of the accident. These simulated accidents are subsequently included to the map material which can show us the impact of the accident in dependence on time and quantity. Thanks to these software means it is possible to identify the negative effects of the accidents and take the necessary preventive measures. These simulation programmes work with various databases thanks to which we can simulate the accidents as realistically as possible.

However, it is necessary to say this software cannot create a fully accurate model of the real world and define all parameters, e.g. the structure of the terrain, location of the buildings and equipment, etc.

Today there are a lot of simulation programmes determined for simulating the accidents, e.g. ALOHA, EFFECTS, BREEZE, TEREX, ROZEX, SAVE II, etc. They can be used for various types of accidents – the simulation of explosions, fires, leakages of hazardous substances to the air, evaporation of the hazardous substances, etc. [28, 29].

In the Czech Republic they most frequently utilise the simulation programme EFFECTS but the programmes ALOHA and SAVE II are also used. Only exceptionally they make use of the programmes TEREX and ROZEX. On the contrary, in Slovakia we often utilise ALOHA.

For simulating the type scenario in the emergency plan framework we chose the software ALOHA, particularly the version 5.4.7. The faculty student Lukáš Dančo participated in realising this simulation. The software simulated a leakage of a hazardous substance from a storage container. The software MARPLOT that is directly connected with ALOHA was subsequently used as a map basis for transferring the graphical outputs from ALOHA and thus for depicting the expansion of the hazardous substance fumes.

The particular company deals with manufacturing the basic chemicals and chemical products and its basic products are the essential amino-acids. Based on exceeding the threshold value of the hazardous substance present in the company, it belongs to the B SEVESO category.

Particularly, it is the hazardous substance ammonium hydroxide – the ammonia.

The ammonia stored in this company has a concentration higher than 25%. It presents a risk for the life and health of people only in the case of leaking from the storage containers or pipelines due to releasing the gaseous ammonia bound in water. The gaseous ammonia or the anhydrous ammonia (according to the law about MIA prevention) is the hazardous substance mentioned in the law in the Appendix 1, part 2. The substance is dangerous based on its classification as the toxic and ecotoxic material.

It is a caustic liquid with bad smell. Its colour range is from colourless to yellow or slightly turbid. This substance causes failures of the central nervous system and irritates mainly the respiratory system. The gaseous ammonia released from this liquid can be easily recognised already in a low concentration thanks to its strong odour. The exposure to a high concentration of the gaseous ammonia can cause the respiratory arrests.

The leakage of this hazardous substance can develop either in the storage containers or during pumping the hazardous substance from the tank truck. We aim at the storage containers, particularly at one of the containers, during the simulation of the hazardous substance.

We chose this device due to the fact it is the only storaging object in the company with a larger amount of the hazardous substance and it is the most dangerous equipment in the enterprise.

4.1 Input data

For us to be able to simulate the type scenarios we needed to define the input data in the software. The data about the territory were defined on the basis of the approximate position of the hazardous equipment. It is a locality in the Banská Bystrica region with an altitude of 370 metres above the sea level. The time and date of the emergency was fictitious only for the needs of the simulation – 14th May 2020 at 11:00 am (**Table 4**).

4.2 Simulating the hazardous substance leakage by software ALOHA

Our simulation of the emergency scenario took into account the formation of a crack on the surface of one of the containers causing a leakage of the whole volume of the ammonium hydroxide (63 m3) to the emergency tank (280 m3) during two minutes. Therefore we simulated the emergency scenario as the spill evaporation from the emergency tank (280 m3) on the basis of the defined atmospheric data.

However, it is necessary to say it was not possible to define the atmospheric data accurately as the emergency tank is located under the terrain level and this fact can affect the spreading of the gaseous ammonia. The surrounding buildings and terrain are not accurately defined in the simulation and it can also affect the spreading of the gaseous ammonia [30].

Input Data	
Data about Territory	
Locality	Banská Bystrica region
Altitude	370 m above sea level
North latitude	48°44′ N
East latitude	19°14′ E
Date of accident	14th May 2020
Time of accident	11:00
Chemical Data	
Hazardous substance	Ammonium hydroxide
Concentration	30%
Atmospheric Data	
Wind speed	4.5 m/s
Wind direction	North-west
Height of measuring the wind speed	10 m
Cloudiness	5 – semi-cloudy
Air temperature	19°C
Stability class	C
Inversion	None
Air humidity	70%
Data about Source	
Source	Spill
Size of the spill	280 m2
Volume of the spill	63 m3

Table 4.
Input data.

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Based on the defined input data from the **Table 3** the software ALOHA graphically assessed the safe zones with a different concentration of the hazardous substance – see the **Figure 3**.

For us to understand the designations better, the following text describes the individual effects in the case of exposures to the hazardous substance to one of the zones.

ERPG 1 – Under this concentration the exposed persons can expect a low, insignificant and temporarily fugitive effect to their health within one hour or to perceive a clearly defined odour.

ERPG2 - Under this concentration the exposed persons can expect an irreversible effect to their health within one hour or less or any symptom that would reduce their ability to realise their personal protection.

ERPG 3 - Under this concentration the exposed persons can expect life-threatening effects to their health within one hour [3].

The abbreviation ppm means the amount of the volume parts of the given hazardous substance per million volume parts of the air.

Subsequently these graphical ALOHA outputs were transferred to the map material through the programme MARPLOT for the direction and reach of spreading the hazardous substance from the leakage source to be depicted. This depiction can be seen in the **Figure 4**.

The **Figure 4** shows the zone of the direct threat in the framework of which the persons can be exposed to the life-threatening effects can be found only in the operator's premises or it can partially hit the areas of the surrounding area. The next threat-zone covers several buildings with the services for the citizens. They are especially the bus stop, public road and staff quarters - here we can assume the occurrence of people. The last yellow zone covers only the uninhabited area where no people's occurrence is assumed. The **Table 5** shows the assumed distance of the reach of the threat-zones.

Our model example processed in the software ALOHA presents our attempt to show the risk of the leakage of ammonium hydroxide from the storaging premises in the company. Based on the assigned parameters we worked out a type scenario of leaking the toxic fumes of this hazardous substance. However, as it has been already mentioned, the software is not able to model certain parameters that would affect the spreading of the toxic fume – e.g. the terrain or the building layout.

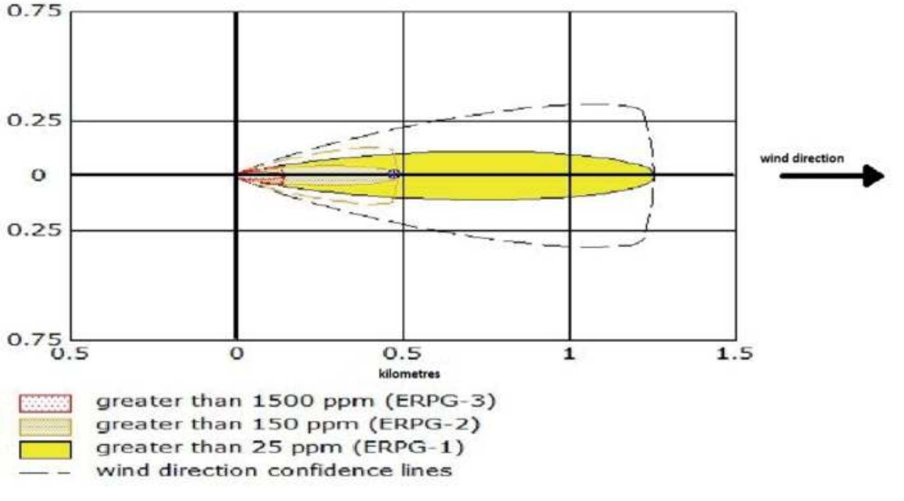

Figure 3.
A graphical depiction of the dangerous zones with the given concentration of the hazardous substance [30].

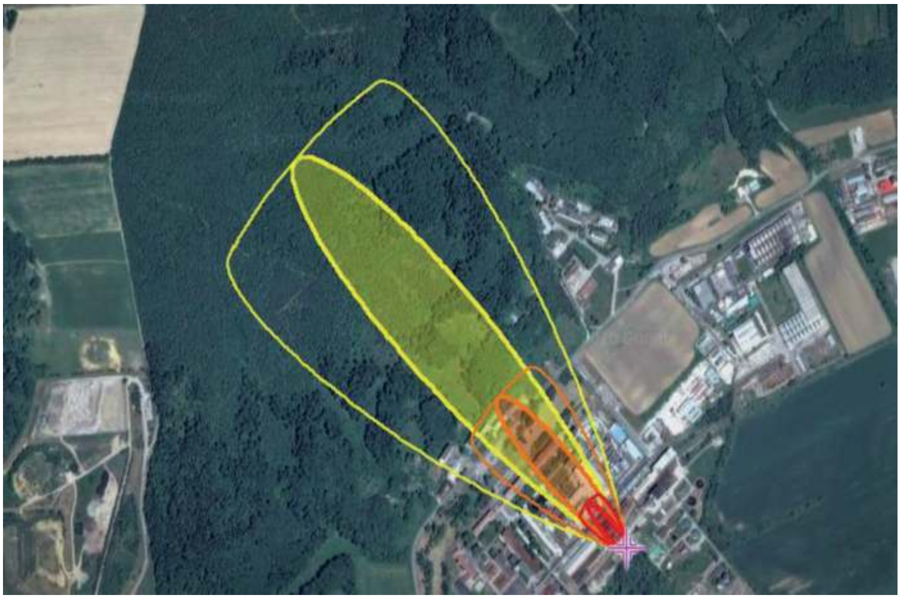

Figure 4.
The reach of the toxic fumes in the map [30].

Threat-zones			
Red	ERPG – 3	1500 ppm	144 metres
Orange	ERPG – 2	150 ppm	487 metres
Yellow	ERPG – 1	25 ppm	1,300 metres

Table 5.
The distances of the threat zones.

Certain safety systems in the company are to be taken into account, e.g. detecting the hazardous substance leakage, warning the employees in the case of the leakage and their subsequent immediate evacuation from the threatened surroundings, etc. Besides these facts there are also the emergency units that are able to affect the spreading process by their immediate response.

Based on the emergency scenario and the aforementioned facts which are not involved in the type scenario we can assume that the leaked toxic fume of the ammonium hydroxide should not exceed the company premises and to threaten the persons in the plant surroundings. We do not assume any impacts on the health of the persons and employees in the company due to their preparedness for such a scenario.

This type scenario was worked out for the needs of depicting the simulation possibilities in the software ALOHA.

5. Discussion and conclusion

Based on the analysis of the risk assessment approaches and type scenarios in the selected EU countries it is possible to say:

- The idea that on the basis of the identified risks in the industrial processes it is necessary to determine the protection zone for the population, its property and the environment for the case of the MIA is essentially the same in the whole EU. However, the approach of determining these zones is different.

- The analysis identified the selected member countries utilised various approaches to this area. Particularly they are the approaches based on the consequences/impacts, the approaches based more on the probability or on a combination of these two approaches.

- Each country has different criteria for the risk assessment and for determining the threat zones. It would be suitable to compare these approaches and to assess them on the EU level and subsequently to choose one approach which would be compulsory and the countries would implement it to their legal environment.

We would like to recommend utilising one type of software for modelling and simulating the type scenarios in all EU member states. Although the majority of the software process is based on the basic physical dispersion models, their outputs and thus the distances of the threat zones are frequently not identical. The ALOHA software is a complex tool.

The MIA prevention is one of the assumptions of ensuring the civil safety in the framework of the expanding technological development. The number and effects of the hazardous substances change permanently and therefore the risk assessment and the subsequent risk treatment/management in the industrial processes is the basic prevention principle. The MIA prevention is a complex and interdisciplinary area that is involved both in the European directives and in the regulations of the EU member states that transpose these requirements to their legal environment. In fact it is a tool that is an important attribute during processing the safety documentation of the SEVESO establishment.

Our complex model is based on the routine procedures and provides a broader interface for its implementation. Its verification confirmed the possibility to utilise the methodology especially in the SEVESO establishment by the specialist for the MIA prevention [32, 33]. In spite of the fact, the new law does not define a unified methodology of the risk assessment; the effort of the EU is oriented on creating a unified approach. The advantage of such a procedure would be the possibility of comparing the results of the SEVESO establishments if the same methodology was used.

The main benefit of this article is a complex analysis of the MIA prevention that is created by the legal environment (regulations and technical standards), by the participating parties (the state administration bodies, SEVESO establishments, etc.). The processes that are under way (the managerial and technical ones) and the methods and tools that are utilised (the information systems, methods and techniques of the risk assessment, etc.) both from the EU and the Slovak Republic's point of view. The area of the MIA prevention system is analysed and summarised in this work for the first time since the adoption of the new SEVESO III Directive and the subsequent adoption of the new law about the MIA prevention (2015) in the Slovak Republic.

5.1 Study limitations, implication and future research directions

Our main aim in this study was to show the importance of the MIA prevention. In spite of the fact the preventive measures are increased, its amount does not decrease and it can be caused mainly by the increasing number of the enterprises and the hazardous substances (the new ones) used. The prevention improvement has a direct impact on making the occupational safety of the company but also the public in its close surroundings more effective [31–33]. The company is able to process the risk assessment and subsequently to model it into the visual form better by using the structured procedures and utilising the available software (e.g. ALOHA).

The insufficient information occurring in individual database systems is the possible limitation. The identified causes of the accident and its consequences are often processed insufficiently and it is impossible to identify them. The limitation of the ALOHA system is the extent of its utilisation in the area of spreading the hazardous substances and it is a problem to model the fires and explosions.

Regarding to the created procedures for the risk assessment it would be suitable to integrate the calculation mechanisms to individual steps of the risk assessment. It would be also suitable to aim at utilising the tree methods for determining the causes and effects, especially by using the bow-tie diagrams. Another opportunity is also to create the corresponding methods of the risk assessment for the domino effects or zoning and permission activities.

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