Verification of Risk Assessment and Treatment model and Software tool in Chemical Establishments in Slovak Republic

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Abstract: The major industrial accidents prevention is one of the principle conditions for ensuring the security and safety of the employees and citizens living close to the industrial establishments. The most hazardous industrial establishments in the EU are called the "SEVESO establishments" and their number is about 10,000 in the framework of all EU countries. Until June 2015 the individual member states are to transpose the new directive SEVESO III to their legal environment. In the implementation framework there is space for the individual member states to identify the problem areas in the existing legal environment and to implement new approaches especially for the risk assessment and treatment. Regarding to the space that was created during the SEVESO III transposition, it is possible to suggest unified procedures and methodologies which could be used by the enterprises for these types of analyses. This paper summarizes research results and recommendations (of University of Žilina in Žilina) in area of industrial accidents prevention in Slovak republic based on ongoing verification of created quantitative risk assessment and treatment model and software tool in two chemical establishments. The advantage is especially utilizing the bow-tie diagrams which link the fault trees and event tress and in this way create a possibility to utilize the generic trees for carrying out an analysis. Also a whole range of other methods and techniques can be utilized in the individual steps of this systematic model. This approach should be considered after its validation to be used in all SEVESO establishments in Slovak republic in the future and therefore it will be possible to compare results of analysis between SEVESO establishments in Slovak republic.

Keywords: ARAMIS, Risk Assessment and Treatment, industrial accident

1. INTRODUCTION

The major industrial accidents prevention is a specific area in the framework of the process of planning and solving the crisis phenomena not only in the Slovak Republic but also on the international level. The European Union decided to solve the area of the major industrial accidents in 1982 through a legal tool called the "SEVESO Directive" which has been amended twice so far. Currently the SEVESO II Directive is valid and until 2015 the new directive SEVESO III has to be transposed to the legal environment of the EU member states. These legal tools determine the rules for handling with the hazardous substances and keeping the rules how to handle them. The Slovak Republic as an EU member has about 80 SEVESO companies in its territory and attempts to fulfil all requirements of the valid directives and to ensure sustainability of the interests protected. There are approximately 10,000 SEVESO companies in the European Union.

2. BASIC ACTIONS

The transposition of the new SEVESO III Directive creates a space for improving the problem areas which have been identified by the statistical research [3,4]. The most important actions for the proposed changes in the framework of the SEVESO III are as follows:

- harmonising the Appendix 1 with the EC regulation No. 1272/2008 on classification, labelling and packaging of substances and mixtures (further only CLP regulations), amending and repealing Directives 67/548/EEC and 1999/45/EC to which the SEVESO II Directive refers. The CLP rules will become effective on 1st June 2015,
- strengthening the effectiveness of regulations concerning the access of general public to information about security and safety, participation in the decision-making process and

enforcement of justice as well as an improved method of collecting, managing, sharing information and its accessibility,
- more strict rules for carrying out inspections of the premises with the goal to ensure effective realisation and enforcement of the stated rules are being stated. [2]

Further changes comprise technical adaptations and simplifications which will reduce the unnecessary administrative burden. In the framework of the transition period there is a space for the member states not only to adapt to the identified changes but also to alter the existing and routine procedures in some areas especially during processing security and safety documentation and its most important parts. Undoubtedly, one of these parts is also the risk assessment and management, an area which creates the basic assumption for reducing the possibility of the rise of a major industrial accident by implementing preventive measures.

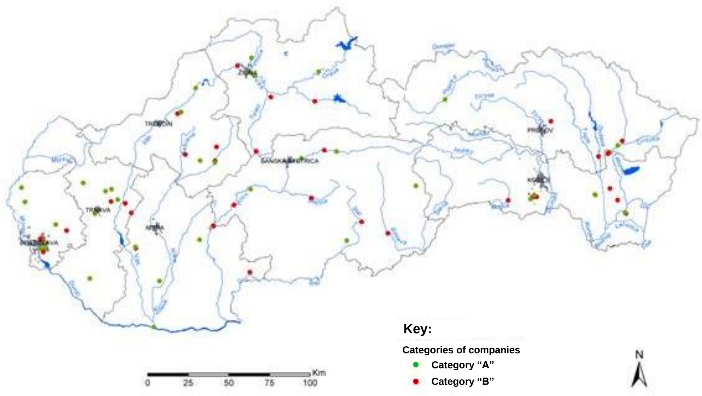
The need of solving the area of the risk assessment and management is supported also by the investigations on the European but also national level. [3,4] The selected conclusions which affect the adoption and adaptation of the legal environment in the Slovak Republic are based on a statistical research realised during 2012 – 2013 in the framework of the MOPORI project under the title „Statistical Research of the SEVESO companies“. The statistical research started in 2011 by meetings with competent bodies and creating questions for the questionnaire. Subsequently we accomplished the list of persons in the framework of the companies who were sent the questionnaire – this required involvement of several project team members in this action (81 companies were addressed). The information obtained was often inaccessible and incomplete, but even outdated. The project team as well as the firm RISK CONSULT s.r.o. (which actively participated in this action) had to remind repeatedly the addressed to companies to send the questionnaires.

81 SEVESO companies from 26 lines of business in the Slovak Republic were addressed in the framework of the project solution (see the figure 1). The following facts affected the representative character of the research:

- the questionnaire was filled in and returned by companies from 16 lines of business – a success rate of 62%,
- out of 81 SEVESO companies 44 firms sent the filled in questionnaire - a success rate of 54 %,
- 16 lines of business filled in and returned the questionnaires. Out of the 70 addressed companies 42 questionnaires were returned - a success rate of 63 %. [3]

The SEVESO companies can be investigated on the selected representation rate of 50 % and the achieved results and conclusions can be referred to 14 lines of business. [3]

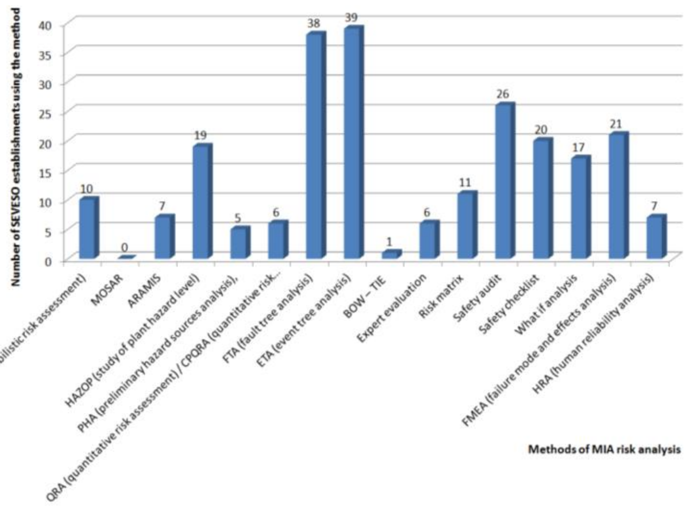
Figure 1 Distribution of establishments falling under the scope of MIAP act in Slovak Republic (Source: http://www1.enviroportal.sk/indikatory/detail.php?kategoria=263&id_indikator=4425 , 2012)



Although the statistical research contained 29 questions, several of them had a principal influence on the model. The utilisation of the methods and techniques for the risk assessment and management is one of the bases and usable results for creating a complex model which results from the investigation.

The most common methods utilised by the experts in the SEVESO companies were ETA – Event Tree Analysis (39 companies), FTA – Failure Tree Analysis (38 companies) and Security and Safety Audit (26 companies). [3] The figure 2 shows a thorough overview about distribution of the methods for analysing the major industrial accidents according to the experts´ knowledge in the area of the major industrial accidents prevention.

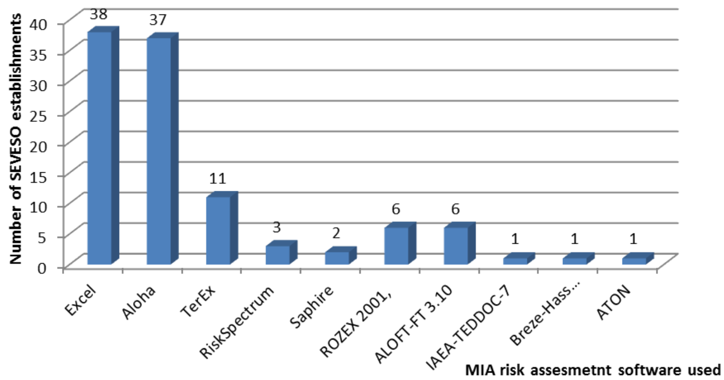
Figure 2 Numbers of SEVESO establishments adopting various methods of MIA risk analysis [3]



In the framework of the EU regulations as well as the law about major industrial accidents prevention there is no determined software tool used for creating scenarios, modelling the consequences and impacts, however, there are concrete inputs for calculating the summarised expression of the impact seriousness. Currently there are several software products which can be used. They differ by their prices and variedness of inputs as well as different user environment.

The question concerning the usage of the software for assessing the major industrial accidents was answered by all 44 SEVESO companies. The answers show the companies utilise the following software means for assessing the major industrial accidents: Excel, Aloha, TerEx, RiskSpectrum and Saphire. The companies do not use any other software for assessing the major industrial accidents listed in the questionnaire. The companies could also introduce other software they use for assessing the major industrial accidents. The following ones were introduced: ROZEX 2001, ALOFT-FT 3.10, IAEA-TEDDOC-7, Breze-Hass profesional, ATON. The dominant part of the companies (38 companies, 36%) uses EXCEL and Aloha (37 companies, 35%). The programme ATON seems to be introduced by a mistake. The overall distribution of the companies according to the software used for assessing the major industrial accidents is shown in the figure 3.

Figure 3 Number of SEVESO establishments preferring software products for risk assessment [3]



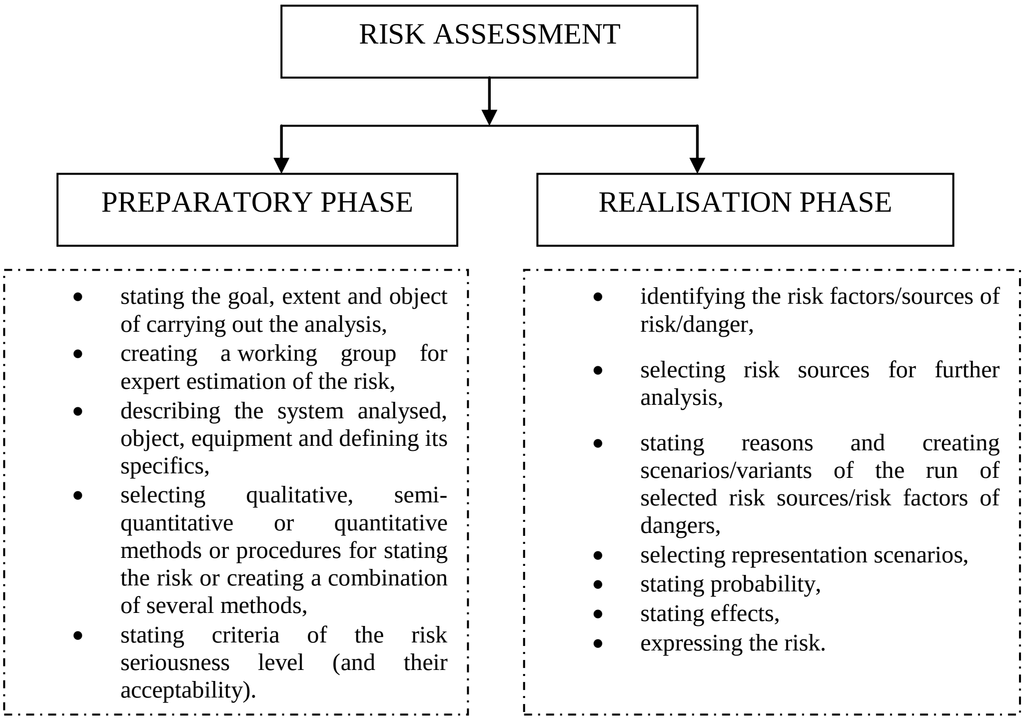
Based on several outputs from the aforementioned statistical investigations, consultations with experts, analyses of the current state in this area and other accessible information we created the **Complex Model for Risk Assessment and Treatment of the Industrial processes** which is explained in the next parts.

3. COMPLEX MODEL FOR RISK ASSESSMENT AND TREATMENT OF THE INDUSTRIAL PROCESSES

Based on a comprehensive analysis of the current state of the approaches to assessing and managing the risks, methods, techniques and tools used in individual steps, the existing legal standards, the research realised in the project framework and bases and specifics characteristic for a particular country, we created a model for assessing and managing the risks of industrial processes. Subsequently individual methods, techniques and tools from the ARAMIS methodology, the created software and other methods and approaches were implemented. Therefore this model can be characterised as a comprehensive one and it can be implemented for a particular technological process.

In the further text we will explain a simplified approach to implementing the model which complies with the routine procedures in this area.

Figure 4 Simplified approach to risk assessment [1]



The individual phases together with recommended utilisation of the methods and techniques in the individual steps will be explained in the text to come.

3.1 PREPARATORY PHASE

Stating the goal, extent and object for realising the analysis. The operator of the risk technology is obliged to ensure the assessment of the risks in connection with carrying out all steps to prevent the rise of a major industrial accident in compliance with the law about major industrial accidents prevention.

Creating a working group for an expert estimation of the risk. The given analysis is carried out by professionally capable persons who are dealing with the area of assessing and managing the risks and who utilise the knowledge of specialised workers who understand the technology being assessed (e.g. foremen from production, mechanics, maintenance workers, security and safety technicians, etc.).

Describing the system, object and premises analysed and defining their specifics. The information which is of a general and specific character enters the analysis.[11]

General requirements on the input information from the ARAMIS methodology:

- the documentation of the system/object being assessed,
- describing the running technological processes,
- describing the devices and pipelines,
- the list of hazardous substances used in the assessed object/subject/technology and their connection with the identified equipment,
- summarising the cards of security and safety data and information for the analysis.

Specific information necessary for every identified equipment/device:

- the name of the device,
- the volume and dimensions,
- the service pressure and temperature,
- the substances handled,
- the substance state,
- the quantity of the substance in the identified equipment (in kg or kg/s),
- the boiling point of the hazardous substance.

Selecting the qualitative, semi-quantitative or quantitative methods or procedures for stating the risk or creating a combination of several methods. Based on the previous analyses and investigations the methods HAZOP and individual parts of the ARAMIS methodology were chosen. Based on re-evaluation some procedures of this methodology were adapted for the current conditions.

Stating criteria for the seriousness of the risk level (and their acceptability). In this step we have to determine the social acceptability of the risk of a major industrial accident from the point of view of assessing the possibility of threatening life of one or several persons and it is defined by the acceptable probability or the frequency of occurring a major industrial accident and this is assessed according to the following relation:

- If life of one person is endangered

$F_{pr} = 10^{-5}$ for the existing companies
$F_{pr} = 10^{-6}$ for new companies or premises

- If lives of several persons are endangered

$F_{pr} = 10^{-3}.N^{-2}$ for the existing companies and premises
$F_{pr} = 10^{-4}.N^{-2}$ for new companies and premises. [12]

In the end there is the assessment of the risk acceptability according to values introduced in the law.

3.2 REALISATION PHASE

Identifying the risk factors/ the risk source/the danger. This phase consists of identifying the following risk factors:

- the list of selected hazardous substances (SHS) (comparison with reference values),
- identifying dangerous devices.

First of all it is necessary to choose those hazardous substances (based on the cards with the security and safety data from the preparatory phase) which can be designated as selected/specified. The SHS are then compared with the existing list of the selected hazardous substances listed by the SEVESO II or SEVESO III Directive. If the selected hazardous substance (according to the corresponding legal regulation) exceeds the reference value introduced in the tables of the law about major industrial accident prevention and shows a dangerous property, the company is categorised into the class A and B.

The list of SHS, which are bound to a particular device, should be the output of this step. The devices are introduced in the table – List of Dangerous Devices – in the ARAMIS methodology and the individual devices are designated from EQ1 to EQ16.

Stating the causes and creating the scenarios/variants of the selected risk sources/ risk factors and dangers. The identified SHS and devices are subsequently attached to critical events:

- Decomposition (CE1),
- Explosion (CE2),
- Materials set in motion – entrainment by air (CE3),
- Materials set in motion – entrainment by liquid (CE4),
- Start of fire (LPI) (CE5),
- Crack of casing in vapour phase (CE6),
- Crack of casing in liquid phase (CE7),
- Leak from liquid pipe (CE8),
- Leak from gas pipe (CE9),
- Catastrophic crack (CE 10),
- Vessel collapse (CE11),
- Roof collapse (CE12). [17]

Subsequently, based on the identified critical events in connection with the SHS and devices, we create the bow-tie diagrams which are a principal contribution in the area of the major industrial accidents prevention. In the framework of the project solved at the University of Žilina in Žilina we created software means in the user environment Excel. [3] The basic tree structure was taken over from the ARAMIS and the calculation rules were adapted to the currently used approaches in the Slovak Republic. The selection for implementing barriers to the individual trees was left open; the investigators themselves enter their name as well as the success level. On Figure 5 there are presented created bow – ties within software tool.

Figure 5 List of bow-ties created within Software tool and adapted to Slovak republic conditions

	Generic fault tree (FT)	Zložitosť	Critical event	Nr. CE	Event tree (ET) - Substance state (STAT)	Zložitosť
1	FT Chemical decomposition	4	Decomposition	CE1	STAT1 Solid	1
2	FT Decomposition tied to a punctual ignition source	3	Decomposition	CE1	STAT1 Solid	0
3	FT Thermal decomposition	2	Decomposition	CE1	STAT1 Solid	0
4	FT Explosion of an explosive material	5	Explosion	CE2	STAT1 Solid	1
5	FT Explosion (violent reaction)	5	Explosion	CE2	STAT1 Solid	0
6	FT Materials set in motion (entrainment by air)	1	Materials set in motion (entrainment by air)	CE3	STAT1 Solid	1
7	FT Materials set in motion (entrainment by a liquid)	1	Materials set in motion (entrainment by a liquid)	CE4	STAT1 Solid	1
8	FT Start of fire (Loss of Physical Integrity)	2	Start of fire (LPI)	CE5	STAT1 Solid	1
9	FT Start of fire (Loss of Physical Integrity)	0	Start of fire (LPI)	CE5	STAT2 Liquid	1
10	FT Start of fire (Loss of Physical Integrity)	0	Start of fire (LPI)	CE5	STAT3 Two-phase	1
11	FT Start of fire (Loss of Physical Integrity)	0	Start of fire (LPI)	CE5	STAT4 Gas / Vapour	1
12	FT Large breach on shell or leak from pipe	6	Breach on the shell in vapour phase	CE6	STAT1 Solid	0
13	FT Large breach on shell or leak from pipe	6	Breach on the shell in vapour phase	CE6	STAT3 Two-phase	1
14	FT Large breach on shell or leak from pipe	6	Breach on the shell in vapour phase	CE6	STAT4 Gas / Vapour	1
15	FT Medium breach on shell or leak from pipe	3	Breach on the shell in vapour phase	CE6	STAT1 Solid	0
16	FT Medium breach on shell or leak from pipe	3	Breach on the shell in vapour phase	CE6	STAT3 Two-phase	0
17	FT Medium breach on shell or leak from pipe	3	Breach on the shell in vapour phase	CE6	STAT4 Gas / Vapour	0
18	FT Small breach on shell or leak from pipe	3	Breach on the shell in vapour phase	CE6	STAT1 Solid	0
19	FT Small breach on shell or leak from pipe	3	Breach on the shell in vapour phase	CE6	STAT3 Two-phase	0
20	FT Small breach on shell or leak from pipe	3	Breach on the shell in vapour phase	CE6	STAT4 Gas / Vapour	0
21	FT Large breach on shell or leak from pipe	0	Breach on the shell in liquid phase	CE7	STAT2 Liquid	1
22	FT Large breach on shell or leak from pipe	0	Breach on the shell in liquid phase	CE7	STAT3 Two-phase	1
23	FT Medium breach on shell or leak from pipe	0	Breach on the shell in liquid phase	CE7	STAT2 Liquid	0
24	FT Medium breach on shell or leak from pipe	0	Breach on the shell in liquid phase	CE7	STAT3 Two-phase	0
25	FT Small breach on shell or leak from pipe	0	Breach on the shell in liquid phase	CE7	STAT2 Liquid	0
26	FT Small breach on shell or leak from pipe	0	Breach on the shell in liquid phase	CE7	STAT3 Two-phase	0
27	FT Large breach on shell or leak from pipe	0	Leak from liquid pipe	CE8	STAT2 Liquid	0
28	FT Large breach on shell or leak from pipe	0	Leak from liquid pipe	CE8	STAT3 Two-phase	0
29	FT Medium breach on shell or leak from pipe	0	Leak from liquid pipe	CE8	STAT2 Liquid	0
30	FT Medium breach on shell or leak from pipe	0	Leak from liquid pipe	CE8	STAT3 Two-phase	0
31	FT Small breach on shell or leak from pipe	0	Leak from liquid pipe	CE8	STAT2 Liquid	0
32	FT Small breach on shell or leak from pipe	0	Leak from liquid pipe	CE8	STAT3 Two-phase	0
33	FT Large breach on shell or leak from pipe	0	Leak from gas pipe	CE9	STAT1 Solid	0
34	FT Large breach on shell or leak from pipe	0	Leak from gas pipe	CE9	STAT3 Two-phase	0
35	FT Large breach on shell or leak from pipe	0	Leak from gas pipe	CE9	STAT4 Gas / Vapour	0
36	FT Medium breach on shell or leak from pipe	0	Leak from gas pipe	CE9	STAT1 Solid	0
37	FT Medium breach on shell or leak from pipe	0	Leak from gas pipe	CE9	STAT3 Two-phase	0
38	FT Medium breach on shell or leak from pipe	0	Leak from gas pipe	CE9	STAT4 Gas / Vapour	0
39	FT Small breach on shell or leak from pipe	0	Leak from gas pipe	CE9	STAT1 Solid	0
40	FT Small breach on shell or leak from pipe	0	Leak from gas pipe	CE9	STAT3 Two-phase	0
41	FT Small breach on shell or leak from pipe	0	Leak from gas pipe	CE9	STAT4 Gas / Vapour	0
42	FT Catastrophic rupture	4	Catastrophic rupture	CE10	STAT1 Solid	1
43	FT Catastrophic rupture	4	Catastrophic rupture	CE10	STAT2 Liquid	1
44	FT Catastrophic rupture	4	Catastrophic rupture	CE10	STAT3 Two-phase	1
45	FT Catastrophic rupture	4	Catastrophic rupture	CE10	STAT4 Gas / Vapour	1
46	FT Vessel collapse	1	Vessel collapse	CE11	STAT2 Liquid	0
47	FT Collapse of the roof	1	Collapse of the roof	CE12	STAT2 Liquid	1

Stating the probability. Based on the created bow-ties for the stated critical event it is necessary to determine the probability/frequency of the causalities which are on the FTA side. The partial frequencies/probabilities of causes are written directly into the created software and relations according to the Boolean algebra re-calculate the frequencies which enter other knots. Also the probability/frequency and barriers in every branch are mutually in an interaction.

According to ARAMIS the frequency of the critical event moves in the range of F0 to F4 – the F0 is attached to the event with the highest frequency and F4 with the lowest one.

Stating the consequences and impacts. In the end, the impacts of an accident are determined (based on the created bow-ties). Before we define them, it is necessary to simulate the development of the crisis phenomenon by appropriate software for us to find out the extent of the hit area. Based on this simulation we subsequently determine the impacts on life, property and environment through the C1 – C4 indicators.

The impact classification is based on the assessment of the effects on human targets and effects on the environment.

Expressing the risk (stating the risk and determining the risk perception acceptability). In the end it is necessary to identify if the stated risk value is acceptable or not. In the Slovak Republic we stated these values as the individual and social risks.

4. IMPLEMENTATION OF THE COMPLEX MODEL IN PRACTICE

For the time being, the verification of the model created is under way in two Slovak enterprises. The first is *Mondi SCP, a.s* and the second one *EVONIC Fermas s.r.o*.

The negotiations with the companies lasted several months and the real implementation has started in 2014. The principal aim of this implementation is to assess the possibilities of utilising the created model in the Slovak conditions as an alternative of the currently used PSA method.

In *Mondi SCP Ružomberok* the identification of SHS is currently under way (after studying the necessary documents), the SHS are attached to the devices and subsequently we state the critical events. The whole analysis is realised on the workplace RK2 – the reaction boiler 2. There are several types of the identified hazardous substances the operators come into contact with (e.g. green/black lye, natural gas,...). Now we are studying the cards of the security and safety data and adapt the information to the currently used regulations.

There is an intensive communication with the company regarding to the possibility to publish the results of the model implementation which have not been confirmed yet and therefore it is not possible to publish the sensitive information. We will continue according to the steps introduced in the chapter 3.

Another group is dealing with implementing the created model in the company *EVONIC Fermas*,s.r.o, which works with ammonia water. First of all it was necessary to carry out tests with the ammonia water in the labs of the University of Žilina in Žilina.

The results show that the speed of releasing the NH3 depends on the temperature of the surroundings/sample and the solution concentration, especially during the initial evaporation phase. Due to the endothermic character of evaporation the lotion temperature reduces quickly under the surrounding temperature – this is proved by the approximation of the curves of individual measurements. During the UNI 2 measurements which are carried out under the ambient temperature of 20°C, the sample temperature was only 11°C.

This information enters further analyses. The same is underway in the company *EVONIC Fermas, s.r.o* in the framework of the preparatory phase and beginning of the realisation stage.

5. CONCLUSION

The major industrial accidents prevention is one the basic pillars for ensuring the citizens´ security and safety – both in the position of an employee or concerned general public. Due to the dynamics of the technological processes and the quantity of hazardous substances currently used in production it is necessary to look for such tools and methods which will reduce the danger of the rise of industrial accidents to the lowest possible level.[13]

The basic contribution of this paper is that it states the approach for the risk assessment and management which we recommend to utilise in the SEVESO companies. The designed model can be utilised as a whole but also some of its parts included especially in the systematic approach ARAMIS which complies with the currently used approaches for assessing and managing risk worldwide as well as in the Slovak Republic. Its advantage is especially the utilisation of the bow-tie diagrams which connect the failure trees and the event trees and in this way create a possibility to make use of the generic trees during the analysis. In the individual steps of the created systematic procedure we can utilise also a whole range of methods and techniques presented in this paper.
The issues of a unified approach to assessing and managing risks have their positive but also negative aspects. One of the advantages is especially the possibility to compare the companies from the point of view of the results from the analyses created for the responsible inspection bodies of the state administration. However, on the other hand the companies created their own procedures when the law about the major industrial accidents prevention became effective and purchased their own software which they use for assessing and managing risks and therefore their decision to change their routine procedure has to be justified by the applicability of the procedure and by identifying the advantages against the system being used. The implementation in the companies *Mondi SCP, a.s* and *EVONIC Fermas s.r.o.* was the first step for introducing this model. The assumed completion of the model implementation in both companies is June 2014 and can be possibly presented at the conference. The authors do not assume any detection of different results than in the case of a more utilised PSA method but offer a structural alternative for assessing and managing risks which is at least equally suitable for the chemical factories.

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