

PROPOSAL FOR RISK ASSESSMENT AND MANAGEMENT GUIDELINES FOR SMALL AND MEDIUM-SIZED ENTERPRISES

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INTRODUCTION

In the present-day technologically advanced world, industrial accidents appear ever more frequently, and the field of major accident prevention has become a dynamically developing discipline. With accelerating technical progress, risks of industrial accidents are to be reduced. In the past and also recently, major accidents have represented, owing to their consequences on human health, property and the environment, important events that should be avoided. For large sources of risks connected with handling significant quantities of dangerous substances, the process of risk assessment and reduction is already taking place. For rather small installations, where dangerous substances are present as well, any risk assessment is not required yet. In spite of this, these rather small installations can represent a major accident risk considering their potential locations, e.g. the close proximity to residential areas or assembly places, which increases the risk to the surrounding population. In case of accident in rather small risk sources, significant damage to the environment can occur as well. The majority of these risk sources are there in small- and medium-sized enterprises (SMEs).

At present those enterprises are being selected in the Czech Republic for which on the basis of threshold quantities of dangerous substances given in the Act No. 353/1999 Coll. on major accident prevention (which is the implementation of the European Seveso II Directive), safety documentation in the area of major accident prevention is required. This rather simple procedure according to the cumulative formula has advantages and disadvantages. On the one hand, it decides unambiguously about the placing the enterprise into the category A (lower tier) or B (upper tier establishments). On the other hand, it provides no information about consequential risks posed to the surroundings. In some cases a risk source with a rather small quantity of dangerous substances than the threshold quantity located, e.g. in a densely populated region, represents a greater hazard than a larger source with the quantity of dangerous substances in excess of the threshold situated outside residential areas. That is why works dealing with this topic have concentrated on a proposal for a simple methodology for the determination of societal risk that will be applicable to unclassified risk sources too.

With regard to the above-mentioned facts, the project pursued the following objectives:

1. characteristics of rather small installations representing major accident risks,
2. major accident risk assessment for these installations by using the existing methods,
3. the verification of validity of the newly prepared European methodology ARAMIS – Accidental Risk Assessment Methodology for Industries – and the methodology for the analysis of accident consequences on the environment with these rather small installations,
4. a proposal for guidelines for the assessment of risks of rather small installations representing major accident risks.

The goal of the proposed guidelines is the submission of a possible method of risk assessment of unclassified risk sources (especially in SMEs) that by location or specific process activities can represent significant major-accident risks. The main goal of the submitted methodology is to contribute to the prevention of accidents of unclassified risk sources, because risk identification and assessment is the basic precondition for effective risk reduction and management. The methodology is aimed at helping the operators of unclassified risk sources in voluntary risk assessment by proposing a suitable decision procedure and by offering available tools.

THEORETICAL BASIS FOR THE METHODOLOGY

Below the basis for preparing the guidelines for the risk assessment of unclassified risk sources is presented. For the purpose of the project, the literature search was performed with the aim to collect information on available home and foreign literature concerning the project topic. The result was a finding that a certain number of references related partially with the topic of risk assessment for rather small establishments exist. These documents deal primarily with risk management from the point of view of occupational health and safety, and further personnel, business and production risks. This is why the proposed methodology mainly concentrated on risks of major accidents due to dangerous chemical substances and recommendations regarding suitable guidelines for this assessment of risks.

Furthermore, the legislative analysis in the area of major accident prevention was done and a list of related enterprise management systems was prepared. From these analyses that were already published in the course of project run it is clear that in addition to large companies, there is a need to carry out risk assessment also for SMEs. The seriousness of the chosen topic is proved by recent accidents. Table 1 gives an overview of chosen accidents in Czech Republic's installations unclassified within the scope of the Seveso II Directive (information was acquired from daily newspapers and the Internet).

Table 1. Overview of selected accidents in unclassified installations

Date (dd/mm/yy)	Installation	Cause	Consequence	Damage
14.6.1999	Ice-stadium in Pribram	Ruptured piping	Release of 0.5 t of ammonia into a stream	
1.7.1999	Textile plant Toray in Prostejov	Operator error – pouring 350 kg of sodium hypochlorite into acid solution	Following reaction released chlorine	Mucosa irritation - 7 people
24.7.2000	Malt house at Hodonice near Znojmo	Poor work during cooling equipment repair	Release of 80–100 kg of ammonia into the Dyje River, fish kill	About 500 000 CZK
6.8.2000	Ice-stadium in Stvanice–Prague	Out-of-date equipment of engine room	Release of several kilograms of ammonia	Nobody injured
29.8.2000	Cold stores at Mochovce	Ruptured piping	Release of ammonia	6 seriously injured employees
2.5.2001	Meat combine in Cheb	Damaged sealing of refrigeration compressor	Release of about 15 kg of ammonia, subsequent evacuation of 112 persons	
23.8.2001	Ice-stadium in Prague 10	Maladjustment of cooling equipment and subsequent rupture of valve	Release of ammonia into the surroundings	Nobody injured, damage of tens thousand CZK

(*Continued*)

Table 1. Continued

Date (dd/mm/yy)	Installation	Cause	Consequence	Damage
23.1.2002	Ice-stadium in Liberec	Careless work on pressure piping	Release of about 50 kg of ammonia from pressure piping in engine room, closure of stadium and surroundings, cancellation of prepared match	
17.6.2003	LPG station in Prague 6	Lorry crashed into LPG dispensing pump	LPG release from tank, closure of all the street, later of near tracks of Czech Railways	About 200 000 CZK
31.7.2003	Car repair shop in Mlada Boleslav	Gas explosion (PB bomb vessels or acetylene systems or LPG in car)	Total destruction of repair shop building and close proximity	1.5 mil CZK, 1 dead person
7.8.20003	Meat combine in Prague 6	Defective wiring, negligence, intent	Fire	about 150 mil CZK
22.8.2003	Meat combine at Hroznetin (Karlovy Vary region)	Negligence	Release of about several tens kg of ammonia through the sump into sewerage system and ammonia water into the river	Trout kill in river

Table 2. Examples of typical unclassified sources of risk

Dangerous substance	Example of installation	Notes
ammonia	breweries, dairies, cooling rooms, meat combines, ice-stadiums	ammonia in engine rooms for cooling
chlorine	water treatment plants, in-door and open-air swimming pools	chlorine in 500 kg barrels or 45 kg pressure cylinders
acetylene	pressure cylinder storage areas	most frequently 50 l pressure cylinders containing 8 kg of C_2H_2
LPG	refuelling stations, home tanks, pressure cylinder storage areas	5 m^3 tanks or 10 kg pressure cylinders most frequently

CHARACTERISTICS OF UNCLASSIFIED RISK SOURCES

For the purpose of submitted methodology, unclassified risk sources are defined as manufacturing installations containing a lesser quantity of dangerous substances than are the thresholds prescribed in the Seveso II Directive. At present, the prevention of accidents of these risk sources is not specified in any law, and thus any adequate pressure is put neither on the management nor the reduction of risks in the operation of such installations.

The unclassified risk sources are characterised by properties and quantities of present dangerous substances, i.e. above all toxic, flammable and explosive substances. As examples of typically unclassified risk sources installations with the quantities of ammonia, chlorine and LPG less than 50 t, 10 t and 50 t, respectively, can be presented. It is stated that the number of such unclassified risk sources in the Czech Republic is hundreds to thousands in order (Mika 2004). Table 2 presents examples of frequent unclassified risk sources.

SUITABLE METHODS OF THE ASSESSMENT OF UNCLASSIFIED RISK SOURCES

The quantitative assessment of major accident risks was published in various handbooks; among the most significant publications dealing with this topic, e.g. (Lees 2005), (CCPS 1989), (CCPS 2001), (TNO 1997) and (TNO 1999) can be ranked. In the Czech Republic the assessment of major accident risks is defined in the Act No. 353/1999 Coll. as follows:

1. the identification of risk sources,
2. the estimation of consequences of scenarios for major accidents on human health and lives, the environment and property,
3. the estimation of probabilities of scenarios of major accidents,

4. the determination of risk level,
5. the evaluation of the acceptability of major accident risks.

It is the selection of a suitable method that is the key question of risk assessment. Therefore, a brief overview of available methods is given. Many methods that are modifications of several most widely used methods enable risk assessment. The publication (Tixier 2002) summarises the most famous 62 methods of risk assessment. In this connection it is necessary to emphasise that the majority of methods are designated as partial methods because they help merely in specific steps of the whole process of risk assessment, e.g. in hazard identification, the evaluation of consequences or the assessment of probabilities (see Table 3).

The methods of risk assessment can be divided into qualitative and quantitative ones (Stuchlá 2005). As for the next division of the methods, the following three categories can be distinguished (Tixier 2002):

- deterministic – based on the quantification of accident consequences,
- probabilistic – based on accident probability or frequency,
- a combination of the deterministic and the probabilistic approach.

Generally it can be stated that the deterministic methods are used for the analysis of the whole industrial enterprise, whereas probabilistic methods for the analysis of a selected part of the establishment that requires a more detailed and thus more exacting analysis. A trend in risk assessment is the hierarchization of results. Primarily with simple-to-apply methods the results are presented as indexes of risk levels (so-called indexing methods). For the risk sources with the worst indexes, a detailed analysis by more demanding

Table 3. Overview of most widely used partial methods of risk assessment

Method name	Abbreviation
Relative Ranking	RR
Safety Review	SR
Checklist Analysis	CL
Preliminary Hazard Analysis	PHA
What-If Analysis	WI
What-If / Checklist Analysis	WI/CL
Hazard and Operability Analysis	HAZOP
Failure Modes and Effects Analysis	FMEA
Fault Tree Analysis	FTA
Event Tree Analysis	ETA
Cause–Consequence Analysis	CCA
Human Reliability Analysis	HRA

methods is then recommended. A similar approach to risk assessment for the whole industrial enterprises is at first the selection of major risk sources, and only in the second phase then detailed quantitative risk assessment (QRA) for the most severe installations selected in this way. Both these approaches are to reduce the number of installations assessed in detail in the industrial enterprise, to simplify thus the whole risk analysis and to concentrate attention especially to the most severe risk sources. It is necessary to state that any unique method for doing the whole risk analysis does not exist yet. In real-life working conditions several methods should be combined. On these facts the preparation of a suitable procedure for risk assessment for unclassified risk sources was also based.

For the needs of the methodology for unclassified risk sources, rather simple screening and indexing methods were tested. From experience in risk analysis made for large industrial enterprises, the following methods were tested for the purpose of risk assessment for unclassified risk sources:

- Selection Method (according to CPR 18E - Purple Book)
- IAEA-TECDOC-727 Method
- DOW's Fire And Explosion Index Method
- DOW's Chemical Exposure Index Method
- Modelling the consequences of toxic releases by using the ALOHA program.

Up to now, when doing major accident risk assessment attention has been paid primarily to human health, or damage to property. However, many accidents cause environmental damage. Because of the complexity and diversity of specific components of the environment, this assessment is more complicated. That is why new procedures and methods concerned with the detailed assessment of accident consequences on the environment are developed. To the assessment of potential consequences of an accident on the environment, two following approaches can be applied. The first of them can be characterised as the use of existing methods of assessment of risks from long-term loads also for accidental releases (e.g. the method according to Directive 93/67/EEC). The other approach is based on the development of totally new methods of risk assessment for specific conditions of accidental releases into the environment (e.g. H&V Index (MŽP 2003), ENVITech03 (MŽP 2003, programme Proteus).

For the purpose of this methodology, the H&V Index method that was developed at VŠB-Technical University of Ostrava for the assessment of environmental consequences of major accidents was verified. By the method, the severity of accidents in relation to the environment according to the Act No. 353/1999 Coll. can be assessed. The method was recommended by the Ministry of the Environment and published in the Ministry bulletin, Věstník 3/03. The H&V Index method can be used for the purpose of assessing the environmental consequences of accidents due to unclassified risk sources. The method itself, however, takes into account neither installed safety systems nor organisational measures, and thus the results can be overvalued. In spite of this, the method can be successfully used as the primary study dealing with environmental risks.

Table 4. Comparison of partial methods of risk assessment by means of selected criteria

	Limitation of quantity	Other basic limitations	Interpretation of results	Demands for skills	Demands for time
Selection method	no	no	easy	low	low
TECDOC-727	from 200 kg	no	easy	low	low
F&E Index	from 454 kg	only flammable substances	easy	medium	low
CEI	no	only toxic substances	difficult	medium	low
Aloha	no	only toxic substances	easy	medium	low
H&V Index	no	only ecotoxic substances	difficult	medium	medium

COMPARISON OF METHODS BY MEANS OF CRITERIA DETERMINED

The above-presented methods are applicable to the assessment of unclassified risk sources if principles of the methods are correctly understood and results are suitably interpreted. For comparing the methods of risk assessment for unclassified risk sources the following criteria were selected:

- the limitation of the quantity of dangerous substances – the lowest quantity for method applicability,
- other basic limitations – merely some hazardous properties of materials and source types,
- the interpretation of results – categories: easy, difficult, complicated
- demands for skills – categories: low, medium, high
- demands for time – categories: low, medium, high.

Results of the comparison are presented in Table 4.

PROPOSAL FOR RISK ASSESSMENT GUIDELINES

On the basis of the above-presented facts the following proposal for the guidelines on risk assessment for unclassified risk sources was prepared. The proposal for the guidelines rests on the following four levels of risk assessment and management:

1. the identification of unclassified risk sources – comparison of the quantity of dangerous substances present in the establishment and the threshold;
2. preliminary risk assessment for the surrounding population and the environment;
3. the detailed assessment of societal, economic and environmental risks;
4. the management of major accident risks and measures to reduce risks.

For the first step of the guidelines – the identification of unclassified risk sources, which is carried out according to the quantity of dangerous substances present in the installation, approaches in various countries were compared at first. Basic threshold quantities of dangerous substances in the Czech Republic are laid down in the Act No. 353/1999 Coll. as subsequently amended. They were adopted from the European Seveso II Directive. Nevertheless, these threshold values only consider the largest sources of risks (about 150 industrial enterprises in the Czech Republic) and no smaller establishments that can, under certain conditions, represent significant major accident risks as well. As a consequence, these thresholds were compared with the Dutch approach in the methodology Purple Book CPR 18E (TNO 1999), with American thresholds determined by the organisation EPA for including into the RMP (Risk Management Program), further with thresholds given in the guidelines for integrated risk assessment IAEA-TECDOC-994 (IAEA 1998) and with thresholds stated in the European project ARAMIS (ARAMIS 2004), in the framework of which the new harmonized methodology ARAMIS was prepared. Results of the comparison for three selected substances occurring most frequently in unclassified risk sources are shown in Table 5.

It follows from the table that thresholds of the Czech law on major accident prevention (and similarly thresholds of the European Seveso II Directive) are approximately 10 times higher than legal thresholds in the United States and several times higher than thresholds recommended by accepted international methodologies. From this difference it is evident that there is a real need for risk assessment for establishments with lesser quantities of dangerous substances than given in legislation.

From the approaches presented above the approach of ARAMIS methodology was taken for the purpose of this methodology in view of its comprehensibility and the division of substances also according to their states of matter. Specifically, these ARAMIS thresholds were determined in the Belgian method VADE MECUM (DGRNE 2000) used for the selection of installations requiring quantitative risk analysis. These threshold quantities are determined depending upon hazardous properties of substances, their physical states and locations with respect to other hazardous installations.

For the second step of the guidelines – preliminary risk assessment – the comparison of screening and indexing methods used most frequently was made (see above). On the basis of this comparison, the selection method from the Dutch methodology Purple Book was chosen for the following reasons. It complies with all the determined criteria – it is applicable to all dangerous substances without any limitation as far as the quantity is

Table 5. Comparison of threshold quantities of dangerous substances (in tons)

Dangerous substance	Seveso II	Purple book	U.S. EPA	IAEA-994	ARAMIS
Ammonia	50	3	about 4.5	3	1
Chlorine	10	0.3	about 1.1	0.3	1
LPG	50	10	about 4.5	10	1

concerned, result interpretation is easy, demands for skills and time are low. In addition, the selection method is recommended by the Ministry of the Environment of the Czech Republic as a competent authority in the area of major accident prevention when processing the safety documentation of risk sources classified within the scope of the Act No. 353/1999 Coll. The selection method can be taken as universally applicable that by means of basic operational conditions determines a potential hazard of the establishment and decides thus about a need of the next detailed risk assessment.

In this second part of risk assessment for unclassified risk sources, there is necessary to find the distance between the source and the closest residential areas. The distance of 100 m was taken as decisive according to the principle of selection method, i.e. if the indication number A is more than 1, the risk source represents a hazard within the distance of at least 100 m. The choice of this effect distance is also supported by data from the publication IAEA-TECDOC-994 (IAEA 1998), in which recommended distances between the sources and selected industrial enterprises are summarised (see Table 6). If the assessed enterprise occurs within these distances, risk analysis must be made.

For the third step of the guidelines – detailed risk assessment – the suitable comprehensive methodology for risk assessment was selected. To the best known methodologies the chemical process quantitative risk analysis - CPQRA (CCPS 1989) and the already mentioned methodologies Purple Book and ARAMIS belong. The Dutch methodology Purple Book is quite popular and frequently used for the processing of safety reports on unclassified risk sources in the Czech Republic. The methodology ARAMIS was presented at the end of the year 2004 as the outcome of a project of the 5th EC Framework Programme. One of project sub-objectives was to carry out risk analysis by applying the methodology ARAMIS to an unclassified risk source. On the basis of the implemented study the results of which were included into the case study of the guidelines, it is just the methodology ARAMIS that is recommended for detailed risk assessment for unclassified risk sources. This new methodology facilitates in many steps the procedure for detailed risk assessment by pre-defined data. However, considering the demands for skills

Table 6. Criteria of source-residential area distance (IAEA 1998)

Dangerous substances	Industrial activity	Source-residential area distance (m)
Flammable and explosive substances	Petrol filling station	<50
	LPG station	<100
	Piping with flammable liquids	<50
	Pressure cylinder storage areas (25–100 kg)	<100
Toxic substances	Cooling equipment	<100
	Retail storage warehouses of pesticides	<50

necessary for processing the detailed risk assessment, any independent preparation of the study by the operator of unclassified risk source cannot be expected and any potential specialist concerned with such a study can choose any adequate methodology for detailed risk assessment.

The last recommended step of the guidelines for unclassified risk sources is risk management for those installations that were assessed as major accident significant risks. For the purpose of unclassified risk assessment, several most important components of the system of risk management are recommended; above all OECD publications were used (OECD 2003, OECD 2005).

Below a brief summary of the guidelines is presented.

1st level – Identification of unclassified risk sources

Installations are subject to risk assessment by using this methodology if the quantities of dangerous substances present in them exceed thresholds M_N given in Table 7.

If:

(a) the quantity of dangerous substances is smaller that the thresholds M_N given in Table 7, negligible consequences of accidents can be expected and there is no need to continue doing the assessment any more.
(b) thresholds for the classification within the scope of the Seveso II Directive are exceeded, it is necessary to act in accordance with the law.

Table 7. Defined threshold quantities of dangerous substances M_N for unclassified risk source assessment (according to ARAMIS 2004)

	Defined threshold quantity M_N (kg)		
Properties of substances	Solids	Liquids	Gases
1. Very toxic	10 000	1 000	100
2. Toxic	100 000	10 000	1 000
3. Oxidising	10 000	10 000	10 000
4. Explosive (defined by Act 349/2004 in Note 2a)	10 000	10 000	—
5. Explosive (defined by Act 349/2004 in Note 2b)	1 000	1 000	—
6. Flammable	—	10 000	—
7. Highly flammable	—	10 000	—
8. Extremely flammable	—	10 000	1 000
9. Dangerous to the environment	100 000	10 000	1 000
10. Classified by R-phrases R14, R14/15, R29	10 000	10 000	—

2nd level – Preliminary risk assessment

In this phase of assessment the following steps are to be taken:

- the selection of major risk sources on the premises of the establishment (by selection method from Purple Book).
- the finding of distances between the closest residential areas and the risk sources.
- the finding of distances between significant components of the environment, such as watercourses, groundwater sources and components of the territorial system of ecological stability – biocentres and biocorridors and the risk sources.

If:

(a) a population occurs within 100 m from the risk sources and simultaneously these installations were assessed as major risk sources, detailed risk assessment for the population must be done.
(b) there is a potential possibility of damaging the components of the environment (surface water, groundwater, soil, biotic components), the analysis of accident impacts on the environment must be carried out.

3rd level – Detailed risk assessment

(a) For the detailed assessment of risks to the population, the new ARAMIS methodology is recommended, or other methodologies, such as Purple Book, CPQRA, etc. can be used.
(b) For the analysis of accident consequences on the environment, the H&V Index method or other approaches to modelling the contaminant in the environmental components can be recommended.

4th level – Risk management

In a case of sources of risks that were assessed by the detailed analysis, it is necessary to introduce risk management as well. As the basic components of the risk management system the following items can be mentioned:

(1) Major accident risk assessment.
(2) Organisation and employees.
(3) Control of establishment operation.
(4) Control of changes in the establishment.
(5) Emergency planning.
(6) Inspection.

The whole recommended procedure for the assessment of risks of unclassified risk sources is clearly arranged in the Figure 1.

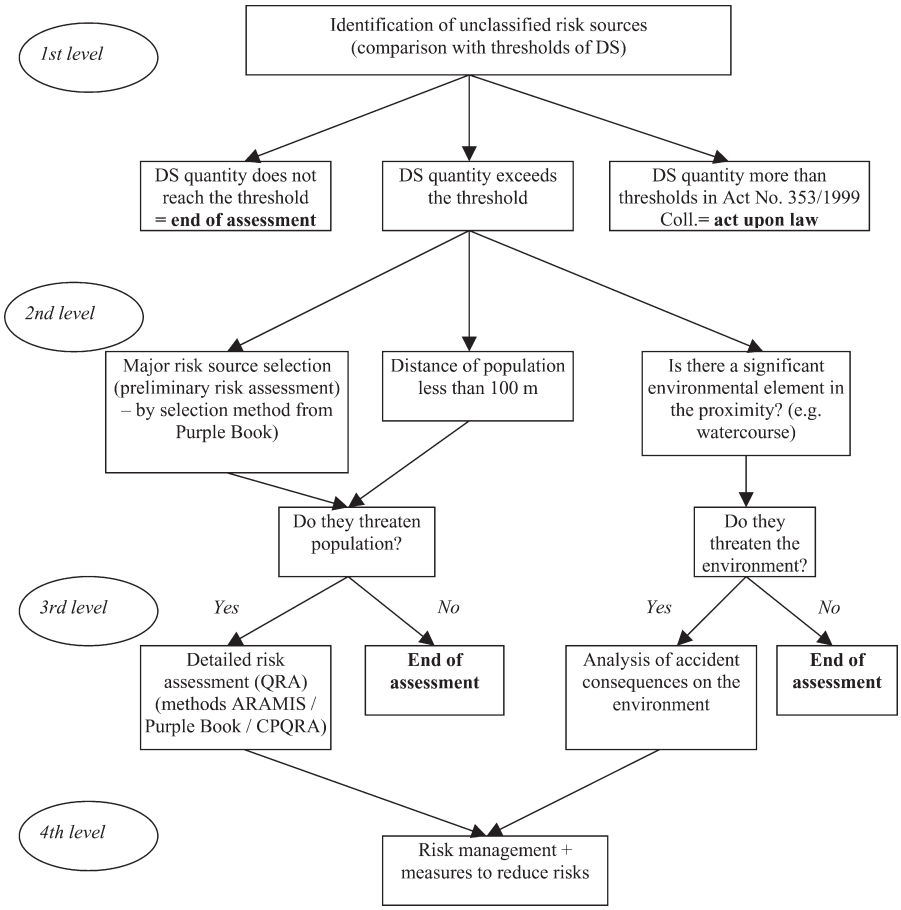

Figure 1. Recommended procedure for the assessment of risks of unclassified risk sources

CONCLUSION

The objectives of the submitted project were to increase awareness of unclassified risk sources, because one of basic conditions of accident prevention is the perception of risks and further a proposal for a suitable procedure for risk assessment for these unclassified risk sources. As risk sources unclassified under the legal effect of Seveso II Directive, e.g. food complexes (breweries, dairies, meat combines), sports facilities (ice-stadiums, swimming pools) and further water treatment plants, pressure cylinder storage areas, refuelling stations and LPG tanks were identified. Obtained results of risk

assessment point to a necessity of doing risk management and also the management of these unclassified risk sources that at present are not from the point of view of accident prevention included into legal regulations, but in spite of this they may represent significant risks of major accidents.

The complete solution of the issue of major accident risk assessment requires an integrated approach based on the knowledge of engineering, natural and societal sciences. The submitted guidelines for the assessment of risks of unclassified risk sources recommend the operators of these establishments a suitable approach by means of several levels, when the depth of and demands for assessment increase gradually. The aim was to ensure as extensive as possible applicability of the guidelines to industries. This methodology can be also used as a tool for the state administration through which the prioritization of risk sources for detailed analysis can be carried out.

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