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Better Protection of the Population in the Zone of Emergency Planning for Major Chemical Accidents in the Czech Republic

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Abstract

The issue of preventing major chemical accidents has been dealt with in the Czech Republic (and in the former Czechoslovakia) for a long time. The first law on this issue was already issued in 1999 on the basis of the European directive SEVESO I from 1982. Many serious chemical accidents from abroad and in the Czech Republic are well known and documented in the professional literature. The new valid law on the prevention of major accidents from 2015 also deals with the protection of the population in emergency planning zones. The implementation of these measures and the level and quality of population protection in emergency planning zones is different. The modelling of emergency impacts also helps to increase the protection of the population in the named zones. A whole range of different SW products and tools are used for this, in the Czech Republic they are mainly the domestic SW tools TerEx and ROZEX-Alarm, or the freely available American ALOHA. Some calculations in the article on the most hazardous industrial toxic gases, toxic vapors or toxic aerosols show how serious a safety issue it is from the point of view of population protection in emergency planning zones. These security issues are discussed in detail in the professional article. In the draft part, the authors present their own previously unpublished set of real, thought-out and justified new or improved measures to increase safety in emergency planning zones in case of possible chemical accidents. Unfortunately, it must be noted that the area of "population protection" is not covered by a separate law in the Czech Republic, while in Slovakia such a law has existed since 1994.

KEY WORDS: *national acts, population protection, prevention of major accidents, hazardous chemical substances, hazardous chemical mixtures, modelling accidental consequences, SW tools, program TerEx, program ALOHA, proposals for increasing population protection*

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1. Introduction

Industrial activity brings together with satisfying of the increasing human needs, a number of negative impacts. One of them is a possibility, which can be connected with the leakage of hazardous substances of toxic, flammable and explosive nature. There is a number of known major industrial accidents in last history, which have had a serious impact on lives and health of humans, environment and property. In order to prevent such accidents, the risk analysis developed for industrial and agricultural activities. [1]

Human health can be affected, directly or indirectly, by routine discharges of hazardous chemical industrial substances or waste from industrial installations or even major chemical accidents could happen. A series of major industrial accidents both at fixed installations and during the transport of hazardous substances in recent 3 decades

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highlighted the urgent need for better management of risk in routine industrial operations and from threat or even existing chemical accidents.

The need for risk analysis connected with industrial safety is growing in developing and also in developed economics to protect humans, domestic animals, environment and property. Integration of safety and its development is closely related to social and economic development of the society and bears a priority in majority of the states.

Development of the risk analyses took place in the engineering practice. The aim of such analyses is to detect the risk, meaning the objects, installations and technologies, which have a high potential to threaten their vicinity and consequently to propose additional organizational and technical safety measures to decrease the risk and increase the safety. It is especially important in a large industrial regions or administrative units such as the regions in the framework in the Czech Republic.

The Czech Republic has the fully implementation of the European Directive SEVESO I from 1982 [2], SEVESO II [3] from 1996 and SEVESO III [4] from 2012 in the national law system. Mentioned directives deal with prevention of major chemical accidents. The named European directives were a necessary basis for the creation of the Czech Republic's own national laws, as discussed below.

The protection of citizens as a system of specialized measures remains an integral part of crisis management and represents its priority in non-military emergency events. Concerning the systematic approach to solve individual types and kinds of emergency events, protection of citizens is understood as a separately controlled and coordinated domain.

High amounts of hazardous industrial chemicals, substances and mixtures are produced, stored, manipulated and transported not only in the Czech Republic but also in many other developed countries. Many of them are found at certain sites such as the industrial zones, which usually include number of companies dealing with hazardous industrial chemicals and substances. The possibilities for misuse of some hazardous industrial chemical substances for terrorist acts or hostile usage are evident. Toxic substances are most prone to misuse. The different dangers of misuse are explained further in text.

2. Method of investigation on the area of prevention of major chemical accidents

On the basis of the worldwide, European, and even home experience, the national Act No. 353/1999 Coll. [5] *"on the prevention of major accidents caused by chemical substances"* was approved in the Czech Republic, too, by the end of 1999 (the first law on the prevention of major chemical accidents in the Czech Republic).

A new and upgraded issue is the national Act No. 224/2015 Coll. [6] The major accidents, which had taken place – and particularly their negative impacts on the lives and health of population, injury to the living environment, and direct and indirect economic and property losses – proved that the issue of prevention and remedy of their consequences should be clearly legislated.

In general, it can be summarized that the Act imposes a series of responsibilities to both individual, as a rule big and medium plants, and to the bodies of the state administration. The purpose of all the measures consists in reducing to minimum the risk of major accidents inception and – in the case of a major accident should arise – the people living in the threatened surroundings – be warned up quickly and reliably on the imminent danger. This, nevertheless, assumes for the ordinary citizen living close to an industry facility to be clearly and in advance informed on the possible major accidents and the ways of being warned up, but mainly on the appropriate and indispensable models of the people's behavior. However, at present time – in accordance with the valid legislation – the responsibility of protecting and informing the population is the full competence of the state administration. But in addition to the state administration, also the autonomous bodies, which as a rule accomplish many tasks and measures of the state administration in the position of the so called "*conferred authority"*, play and important role in the whole system. The segment of population's protection – see Decree of the Ministry of Interior No. 380/2002 Coll. [7], and the like – may serve as examples.

The original concept assuming that only the object or facility of the B group may threaten the population living in the undertaker's area surroundings is not accurate. Practical experience of evaluation of the various manufacturers, their objects and facilities revealed that not only objects and facilities belonging to the A group, but even not classified objects and facilities can represent, and they actually do, a danger for the civilian population living in the vicinity of the manufacture. On the other hand, it should be admitted that those are only rare and exceptional cases. In other words, this means that the breakdown effects of fires (thermal radiation), explosion (pressure wave), toxic leaks (toxicity) get off the manufacturer's area – beyond the manufacturer's fence.

Good information, nevertheless, of the population living close to large industrial enterprises and companies is rather an exception. This is the reality despite the state administration bodies possessing – since the end of the first semester of 2000 – the basic data on hazardous chemical substances and agents at the area under their responsibility. And those data having been completed and enlarged with other detailed data and information rendered by undertakers at the beginning of 2002. But the above stated facts refer to the stationary objects and facilities of different undertakers only, while by roads and railways large amounts of hazardous chemical substances and agents are transported and handled continuously. And the transportation of those substances and agents obviously represents a serious danger as well.

At present time of standing regional arrangement, it must be taken into account that those areas of administration will comprise hundreds of sources of risk, which represent different degree of danger for the civilian population.

Important Questions: *Which sources of risk threaten most the civilian population? Which sources of risk should be objects of special attention? What will be the consequences of the major accidents? How to mitigate the main consequences of the major accidents?*

These are some of the questions, which the proper state administration and autonomous bodies should obligatorily ask. But surely many inhabitants – mainly those of them living close to large manufactures – are interested in them, too. And those and similar questions can be answered by a correctly developed analysis of risks. But such analysis is used to be extremely laborious and require professional knowledge and experience. For analysing the risks of objects and facilities where hazardous chemical substances and agents are located, only a limited segment of analyses of risks are suitable.

Only limited range of the risk analyses fits the risk analysis of the objects and installations containing the hazardous chemical agents and substances. Risk assessment of fixed installations and transport risks connected with hazardous industrial chemical substances could be made correctly according to the booklet IAEA TECDOC-994 from 1998 [8] or IAEA TECDOC-727 from 1996. [1]

This method [1] was developed in the experienced international team and checked during several workshops. Moreover, the method is in effective use from the year 1993 and was revised and modified in 1996. The method has reached significant international prestige – using mostly in the European Union. The method as only one was partly implemented into the Czech and Slovak legislative systems concerning prevention of major industrial accidents.

This method can be used for relatively fast and effective evaluation and assessment both chemical devices, processing systems, plants etc. and all kind of main transport of hazardous industrial chemical substances. The method is appropriate for quick and relative evaluation of the risk, which the citizens and inhabitants are facing especially in the densely inhabited areas in vicinity of the industrial installations (chemical and petrochemical plants) and roads with dangerous transports.

The most difficult point contains mostly difficult and complicated collecting necessary fresh, valuable and reliable data and information about the type and amount of hazardous chemical substances, risk resources.

The First Responders such as members of Fire Fighting Brigades, Ambulance (Fast Emergency Medical Service) and State Police need to be equipped with fast and reliable software tool to quickly evaluate in *"stress conditions"* the accident/incident/event/attack with hazardous chemical substances, both the hazardous industrial chemical substances and the chemical warfare agents.

Release of hazardous industrial toxic chemicals or even chemical terrorist attack by small amount of chemical warfare agents could represent a very serious trouble. This type of attack and following contamination of people, animals, buildings, cars and the environment should be seriously taken into consideration.

The most hazardous chemical substances in fixed installation and on transport could be toxic gases such as phosgene, chlorine and ammonia they can kill and affect a lot of people especially in the areas with high population density, such places as busy residential areas, shopping centers, centers of city, etc. The killing cloud could be, depending on to the local urban conditions and local weather conditions, at least hundreds of meters or even kilometers (in the case of phosgene and chlorine).

It could be checked by free American software ALOHA (U.S.A.) which is available on Internet or by other standard SW tools such as: ROZEX (the Czech Republic), TEREX (the Czech Republic), EFFECTS (the Netherlands), DEMAGE (the Netherlands), PHAST (United Kingdom), SAVE (the Netherlands), DOW INDEX MODEL FOR TOXIC (U.S.A.), CHARM (U.S.A.), DEGADIS (U.S.A.), HEGADAS (United Kingdom), DENZ/CRUNCH (United Kingdom), HASTE (U.S.A.), SLAB (U.S.A.), TRACE (U.S.A.), DRIFT (United Kingdom), NBC WARNING (Denmark), NBC ANALYSIS (Denmark), H-PACK (U.S.A.) [8].

For that purpose, modelling of possible consequences of breakdowns and accidents must be performed. And these consequences may involve fire, explosion (or dispersion of fragments) or leak of toxic substances. All this represents a danger for human beings. A large amount of combustible, explosive, and toxic substances represent the *"breakdown potential"*, which can become evident not only in the case of technological failure or operators' mistake, but it can be misused – relatively easily – for terrorist or hostile purposes.

The potential attacker needs only to know, how to cause for example chemical release of the hazardous source or how to damage it and initiate a crisis situation. Due to human being technical maturity and invention, it is an important threat. There are many misused hazard resources in industrial nations and they are very often located near human settlements. Unfortunately, in future we can expect increase in terrorist's knowledge and creativity and that is why also an increase in importance of this problem for industrial nations in the world.

At the time being, ROZEX-Alarm and/or TerEx (acronym for "terrorist expert") computer programmers are ready to evaluating the accidental consequences of all serious breakdown phenomena (fires, explosions, and leaks of toxic substances). The modelling of possible breakdown consequences is the first, indispensable, and qualified step in the whole process of crisis management and emergency planning.

ROZEX-Alarm and/or TerEx are both the tools for quick impacts and consequences forecast of hazardous chemical materials and tripwire explosive systems. Often the damage of society integrity is the main goal of terrorist misuse of hazardous materials. The model is created as software with connectivity to graphic information system for direct results display in the map. ROZEX-Alarm and/or TerEx are aimed mainly for flexible use by rescue units during the operation to quickly determine the range of area at risk and subsequent measure to protect inhabitants. It is possible to use ROZEX-Alarm and/or TerEx by the operation commander directly at place or by operation officer in command & control center.

The impacts and consequences forecast are based on conservative forecast. In practice it means that the results correspond to such conditions where there occur maximum possible impacts and consequences to the environment – the worst variant.

TerEx (Terrorist Expert) is a software tool designed for quick estimation of the consequences of accidents involving the release of dangerous chemical substances, terrorist attacks using improvised explosive devices or military attacks using chemical weapons. It has extensive use for operative units of the Integrated Rescue System both directly at the scene of the accident and in the control (operations) center. It is also suitable for risk analyses in spatial planning, designing buildings in the vicinity of roads and production plants, insurance, etc. The program provides results even in the absence of accurate input information. The prediction of the consequences is based on a conservative forecast - the results correspond to the conditions under which the maximum possible consequences will occur (the worst option). The basis of the TerEx tool is ten models of extraordinary events that cover various types of accidents and terrorist attacks, as well as a list and detailed description of dangerous substances that are considered in these events. The database includes over 900 hazardous chemical substances.

The crash models are as follows:

- PLUME – Slow evaporation of liquid from a puddle into a cloud,
- PLUME – Prolonged release of gas into a cloud,
- PLUME – Prolonged release of boiling liquid with rapid evaporation into a plume,
- JET FIRE – Prolonged massive gas leak with ignition,
- PUFF – A one-time release of gas into a cloud,
- DEGAS – diffusion of heavy gases,
- POOL FIRE – Burning of a pool of liquid or boiling liquid,
- EXPLOSIVE – Bait Explosive System,
- SPREAD – Spreading of dust particles,
- SPREAD EXPLOSIVE – The spread of dust particles by explosions.

An integrated part of the program is a module for displaying results on a map. At first glance, it is therefore clear how large an area is affected by the dangerous chemical substance and which area needs to be evacuated.

3. Selected modelling accidental consequences from the chemical accidents

The area of prevention of major accidents is an important area in the system of preventive measures in ensuring the safety and security of residents, preservation of the environment and property values. A number of experiences in the field of chemical industrial safety can be drawn from rich domestic information sources, as a lot of professional experience has been gained especially in the last decade. These are mainly the following important areas: in the field of risk analysis and assessment, safety program for the prevention of major accidents, safety reports, internal emergency plan, but also in the protection of the population in the emergency planning zone, informing the population and in other professional areas.

Important and huge risk comes from the industrial toxic substances. Many of them are widely spread both in volume and their amounts are documented by, for instance, the Ministry of Environment in the Czech Republic. This record specifies them in the following order according to their amount and toxicity: phosgene, chlorine, ammonia, hydrogen cyanide, and formaldehyde.

It is mainly ammonia and chlorine which are produced, used and transported in huge volumes and can be encountered on railway and motorway transport and in industrial installations, plants and storage sites.

Many of the risk sources in the Czech Republic include the hazardous toxic substances but they do not fall within cognisance of the Act about Prevention of Major Chemical Accidents. 155 ice-rinks and about 500 or 600 cold stores with ammonia, which may be found in food processing facilities such as breweries, dairy works or slaughter, serve as examples to illustrate the above. But even an amount of one hundred kilograms of ammonia may cause serious impacts or threats for population in vicinity of such risk source. According to the current law objects must be categorized in group A when the 50 tones limit for ammonia is exceeded

Next, three brief tables are presented as the results of modelling accidental toxic releases for three important hazardous industrial chemical toxic substances in the Czech Republic: *phosgene, chlorine and ammonia*. The modelling is prepared for the conditions below and for three different wind speeds at the location of the emergency release (by the SW tool TerEx).

Phosgene (liquid gas) – $COCl_2$

Evaluated as a PUFF - a one-time release of a boiling liquid with rapid evaporation into a cloud. The temperature of the liquid in the device is 20^0C. Total amount of leaked substance: see table 1. Wind speed in the ground layer of the atmosphere 1 m/s and 5 m/s. Character of liquid leakage from the device: spray effect. Type of atmospheric stability: inversion. Type of surface in the direction of diffusion of the substance: industrial surface. Danger to people from a toxic substance (necessary evacuation of people from the point of view of toxic danger): see table 1.

Table 1.

Phosgene Accidental Releases

Leaked Emergency Mass of Substance [kg]	Danger to Persons by Toxic Substance, Toxic Concentration Reach [m] Wind speed 1 m/s	Danger to Persons by Toxic Substance, Toxic Concentration Reach [m] Wind speed 5 m/s
1 000	2 178	1 654
2 000	2 797	2 121
3 000	3 239	2 454
4 000	3 593	2 720
5 000	3 895	2 947
10 000	5 002	3 778
15 000	5 790	4 369
20 000	6 423	4 844

Chlorine (liquid gas) – Cl_2

Evaluated as a PUFF - a one-time release of a boiling liquid with rapid evaporation into a cloud. The temperature of the liquid in the device is 20^0C. Total amount of leaked substance: see table 2. Wind speed in the ground layer of the atmosphere 1 m/s and 5 m/s. Character of liquid leakage from the device: spray effect. Type of atmospheric stability: inversion. Type of surface in the direction of diffusion of the substance: industrial surface. Danger to people from a toxic substance (necessary evacuation of people in terms of toxic danger): see table 2.

Table 2.

Chlorine Accidental Releases

Leaked Emergency Mass of Substance [kg]	Danger to Persons by Toxic Substance, Toxic Concentration Reach [m] Wind speed 1 m/s	Danger to Persons by Toxic Substance, Toxic Concentration Reach [m] Wind speed 5 m/s
1 000	2 242	1 702
2 000	2 880	2 184
3 000	3 334	2 526
4 000	3 699	2 800
5 000	4 010	3 033
10 000	5 149	3 889
15 000	5 960	4 497
20 000	6 612	4 986

Ammonia (liquid gas) – HN_3

Evaluated as a PUFF - a one-time release of a boiling liquid with rapid evaporation into a cloud. The temperature of the liquid in the device is 20^0C. Total amount of leaked substance: see table 3. Wind speed in the ground layer of the atmosphere 1 m/s and 5 m/s. Character of liquid leakage from the device: spray effect. Type of atmospheric stability: inversion. Type of surface in the direction of diffusion of the substance: industrial surface. Danger to people from a toxic substance (necessary evacuation of people in terms of toxic danger): see table 3.

Table 3.

Ammonia Accidental Releases

Leaked Emergency Mass of Substance [kg]	Danger to Persons by Toxic Substance, Toxic Concentration Reach [m] Wind speed 1 m/s	Danger to Persons by Toxic Substance, Toxic Concentration Reach [m] Wind speed 5 m/s
1 000	1 075	821
2 000	1 382	1 053
3 000	1 601	1 218
4 000	1 776	1 351
5 000	1 926	1 464
10 000	2 474	1 877
15 000	2 864	2 172
20 000	3 178	2 408

Scores of people in the Czech Republic do not know properly, how they should be prepared for the emergency matters (which emergency occasion could endanger them at all); how they should conduct during extraordinary events, emergency and crisis situations; what they have to do; what they should carry along in their evacuation luggage; how they can protect their breathing airways and surface of bodies; when, where and how the citizens may and should cooperate with rescue and medical professionals.

Providing population (public) with sufficient information is the main, but only the initial stage of the whole process of preparation population for emergency matters or critical situation and their impacts and aftermath. To prepare inhabitants for emergency matters, other necessary substantial improvement steps should be implemented. Not only the information has to be provided to population, but they should also be familiarized with it. This way citizens (including all family members) obtain some basic knowledge about problems of protection of population.

In order to protect the population (mostly by self-help and by mutual assistance), the process of obtaining skills and habits should continue. The self-help and cooperation are implemented above all in the first and critical minutes of emergency event before professional rescue workers arrive to endangered or already affected place. This critical time is sometimes marked as "10 (or 15) minutes for life" and citizens are usually dependent upon themselves, eventually upon mutual assistance. These first minutes are crucial for living of many humans.

The obtaining and subsequent fixation of sufficient skills and lasting habits of population is essentially complicated and more exacting activity than the previous phase of peruse and learning of the needed information, facts and fundamentals of the actions. It requires the active access to the whole process of preparation of the population for emergency events and their negative consequences. Obtaining skills and habits is then matter of time and repeated training of essential activities, which is the only way to fix habits. The above demanding activities are not popular in the Czech Republic at present. Nowadays, the public is not capable to realize that the obtaining at least basic skills and habits is not only necessary for their self-profit, but it also vicariously innovates cooperation among threatened inhabitants or already stricken population and rescue components in the case of emergency events.

The target of teaching the above subject is the protection against consequences of natural disasters including survival skills (fundamentals of behavior at flood, earthquake, substantive landslip, volcanic explosions, atmospheric disturbances, blaze, avalanche danger), against consequences of escape of hazardous substances to the environment including survival skills (immediate protection of humans at escape of radioactive, chemical and biological agents) and against consequences of release of explosive, flammable or toxic substances.

4. Main proposals for better population protection in emergency planning zones in the country

From the point of view of improving the current state of prevention of major industrial chemical accidents, the following measures are recommended:

A. Processing of a thorough analysis and assessment of industrial chemical risks not only of stationary equipment (as required by Act No. 224/2015 Coll.) but also of chemical risks of road and rail transport. The ideal tool is the international methodology developed and published by the International Atomic Energy Agency under the designation TECDOC-727 [1]. It would be best to process these significant and comprehensive analyses by individual region (the Czech Republic has 14 regions in total) in 2024 and 2025.

B. In 2024, introduce a unified software tool (for example SW tool TerEx) for the assessment of accident consequences both at the level of regional authorities and at the level of individual components of the Integrated Rescue System of the Czech Republic into the *"prevention of major accidents"* system.

C. In the chemical and other process industries in the Czech Republic, also introduce a *"unified SW tool"* for the assessment of accident consequences.

D. In relation to the preparedness of the population for handling industrial chemical accidents, to intensify and make more efficient the *"preparation of the population in emergency planning zones"*, where they are expected by the consequences of the accident. This must apply preferentially to enclosures and devices classified in group B.

E. For a unified understanding of the seriousness of individual adverse events in the chemical and other process industries and the transportation of dangerous goods, introduce the *"assessment of major chemical accidents"* scale, which could and should be similar to the international scale from 1990, with the abbreviation INES for radiation accidents.

F. In the Czech Republic, the State Office for Nuclear Safety has been established, which is responsible for nuclear safety, radiation protection and emergency preparedness for the entire state, as the main areas. Similarly, the State Office for Chemical Safety should be established.

Here it is possible to introduce an academic reflection and reflection in the direction of the European Union. If the European Union successively issued its binding directives SEVESO I, II and III, the question of why the aforementioned directives have not yet been supported by a suitable software tool is on the agenda. This should be used throughout Europe with the possibility of evaluating toxic leaks, accidental explosions and dangerous fires. It is a great pity that this important technical question has not yet been satisfactorily resolved.

5. Conclusions

The chemical safety and security management system has existed in the Czech Republic for a long time. The European Union issued the first SEVESO I directive in 1982, and then two more European directives followed. These

positively influenced national legislation in the field of prevention of major chemical accidents. In essence, every other European directive required the issuance of a new national law on the prevention of major chemical accidents in the Czech Republic, as well as several implementing decrees.

The first law of this type was issued in the Czech Republic in 1999, but currently the valid version is the national law No. 224/2015 Coll.

It is also very important that a total of five implementing decrees for the Prevention of Major Chemical Accidents Act were issued by three ministries of the Czech Republic (Ministry of the Environment, as the guarantor of the entire area, Ministry of Industry and Trade, Ministry of the Interior). In addition, the Ministry of the Environment of the Czech Republic issues many specific *"methodological guidelines"* that are very helpful in the entire complex process and the creation of the required documentation for the *"prevention of major chemical accidents"*.

In the Czech Republic, great attention is paid to both prevention and preparedness for handling major chemical accidents, should they occur. In this area, a very important part is the modelling of accident consequences, which is actually the prediction of an adverse event, or adverse events must be modelled during their origin and course. Although there are special SW tools for modelling in the Czech Republic (e.g. ROZEX-Alarm or TerEx), their use is unfortunately not very common. In addition, the fact that the European Union issued three binding directives SEVESO I, II and III, but did not supply any SW product for modelling dangerous emergency manifestations for toxic leakage, explosion and fire, has a very unfavorable effect. Such high-quality and reliable software from the European Union level would be very useful and timely, and at the same time, in addition to increasing the quality of modelling the main accident impacts, it would certainly contribute to deeper international cooperation in the area under discussion.

In the Czech Republic, attention is also paid to the protection of the population from the emergency planning zone, which, among other things, is mandated by law and implementing decrees. Unfortunately, it is a sad fact that the preparedness of the population to manage possible major chemical accidents is at a low level.

In general, it is possible to end the entire article with the important statement that the prevention of major chemical accidents is essentially a never-ending process. Although much has been done, it is possible to systematically improve the whole area. The protection of the population, not only in emergency planning zones, but in general, must be a high priority for every modern state. Some other ideas for improving the protection of the population can also be drawn from new professional publications from the past year 2025 [9, 10].

Undoubtedly, in the past, the UN industrial safety program APELL (Awareness and Preparedness on Local Levels), the Canadian Program Responsible Care, or the domestic project *"Safe Company"* contributed to this area. Also, the international voluntary standards ISO 14 001 and ISO 9 001 certainly play a very positive role in the continuous improvement of safety and security both in the chemical and other process industries in the Czech Republic.

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