Improving the Environmental Safety by Means of Chemical Monitoring System

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Abstract

To ensure a higher level of safety in the zones endangered by leakage of hazardous substances on the territory of the Moravian-Silesian region, a CHEmical MONitoring system project was implemented - CHEMON. The project aims at reducing the risks of a potential accident with hazardous substances.

The article describes the process of selecting the major sources of risks, opportunities and goals of continuous monitoring of hazardous substances (which not only serves to identify the accident occurred, but also to ensure observation of the spread of a toxic cloud), possibilities to use the existing transmission paths of the unified warning and notification system for alerting the population, informing system to alert people at risk in significant buildings and procedure of notification of the Integrated Rescue System of an accident.

Keywords: resilience, environmental safety, serious accident, chemical monitoring, protection of the population

Introduction

The overall objective of the environmental safety is to protect and to improve environmental quality as one of the basic principles of sustainable development [1]. Environmental quality is rudimental for the health of the population and increases the attractiveness of an area to live, work and invest in. One of the key elements of environmental quality is also the environmental safety with regard to serious accidents with leakages of hazardous substances.

The aim of the chemical monitoring system (hereinafter "CHEMON") is to improve environmental quality and to reduce environmental risks by limiting the consequences of accidents of life, human health and the environment. Chemical Monitoring Process includes the following:

- limiting the amount of leaked hazardous substance;
- monitoring of the progress of toxic cloud spreading;
- warning of the population;
- notification of security forces (integrated rescue system components).

CHEMON project is implemented within the local self-administration unit of the Czech Republic (hereinafter "CR"), on the territory of the Moravian-Silesian Region. Chemical monitoring system was acquired from subsidies drawn from the Environment Operational Programme.

Limitation of the consequences of accidents with leakages of hazardous chemicals in such a comprehensive scope is completely unique, both in the Czech Republic and abroad. Usual are rather the "local systems" that allow only some of the functions of CHEMON system and without direct active involvement of the security forces (eg. for monitoring of the spread of a toxic cloud). In terms of complexity these commonly used systems are at qualitatively lower level.

The standard "monitoring systems" can also include fire detection devices, where some of the information can be transmitted to the centralized protection desks of operational centres of rescue components. Here, however, it is usually only the monitoring of onset of fire, without linkage to leakages of hazardous chemical substances.

Characteristics of the Moravian-Silesian Region

Moravian-Silesian region is the northeastern part of the Czech Republic with an area of approximately 5500 km^2. Seven percent of the territory of the Czech Republic is inhabited by 12.5% of the population, i.e. approx. 1.2 million people. Moravian-Silesian region is characterized by industrial complexes, whose activity is linked with a number of facilities and installations dealing with hazardous chemicals. Potential serious accidents with spills of these hazardous substances threaten the urban environment.

Prevention has crucial importance to protect the environment from disasters caused by humans

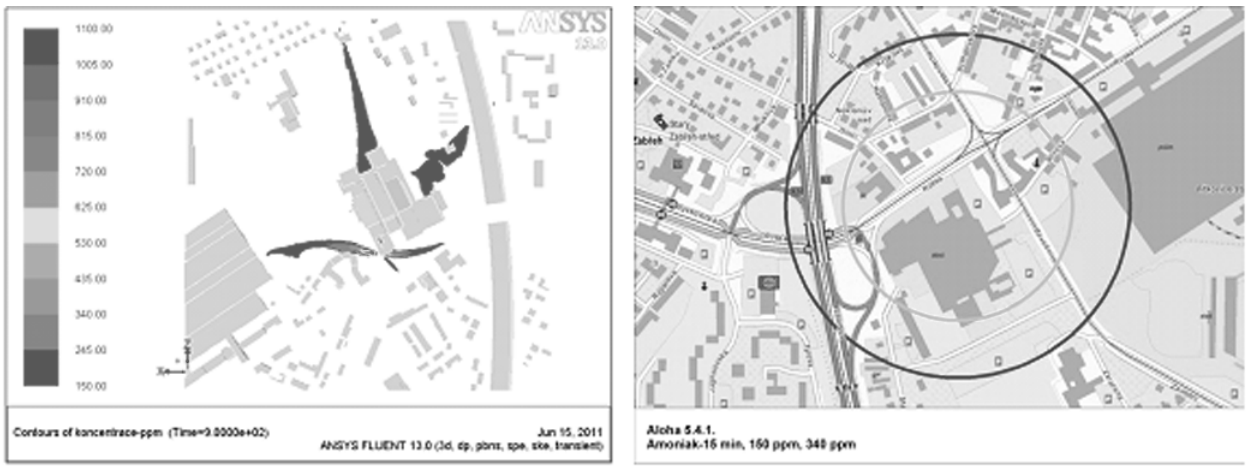

Fig. 1. Ammonia leakage modelling SW Fluent [8] and SW Aloha 5.4.1. (15 minute leakage, range of displayed scale 150 to 1100 ppm, winter stadium CEZ Arena)

Rys. 1. Model wycieku amoniaku za pomocą SW Fluent [8] I SW Aloha5.4.1. (Wyciek 15 minut, zakres skali 150-1100 ppm, Stadion zimowy CEZ Arena)

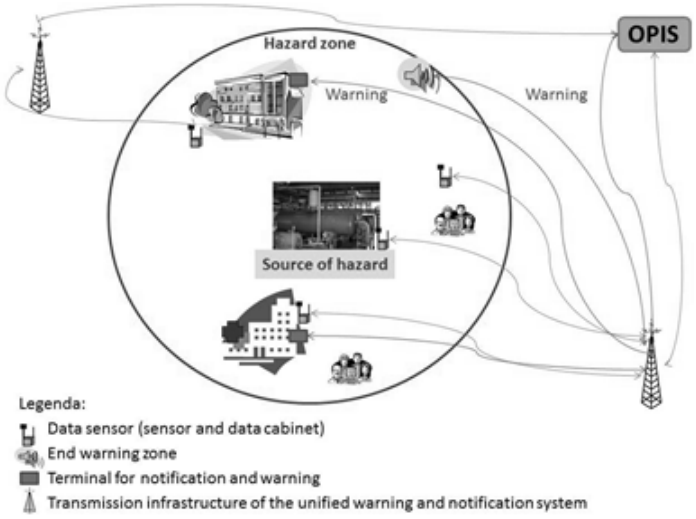

Fig. 2. Schematic representation of the CHEMON system

Rys. 2. Schemat systemu CHEMON

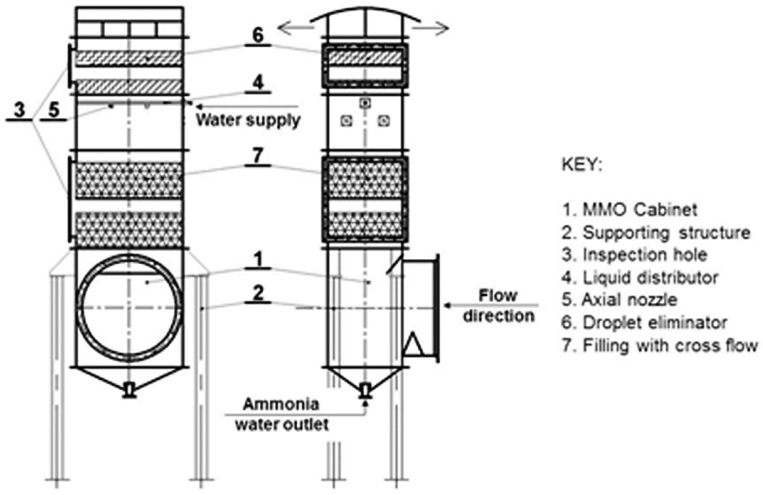

Fig. 3. Diagram of absorption scrubber

Rys. 3. Schemat płuczki absorbera

and natural disasters [2]. The aim is to achieve a higher level of protection against disasters and ensure greater environmental resistance against them. Assessment of risks and their management is crucial for accident management, preparedness and response of environment.

Identification of significant sources of danger

Accidents with spills of hazardous substances belong to the socially significant sources of environmental risks that threaten human health or the environment around the site of accident. It relates not only to operators within the diction of Seveso Directive [3], but also the so-called unclassified operators, particularly entities dealing with compressed or liquefied toxic gases.

Experience from similar accidents in the world shows that it is not possible for the intervening branches to warn and to protect the population in a timely manner and effectively in case of an accident, to start tracking the spreading of the toxic cloud and then implement measures to minimize the consequences. This finding are confirmed also by emergency preparedness exercises.

In the CHEMON project significant resources were identified based on risk assessment, which were subsequently incorporated into the chemical monitoring system. Their selection was performed not only based on the assessment of toxicity and quantity of dangerous substances but also vulnerability of the area. Identified sources of risk mainly include technologies, which use ammonia as a refrigerant (eg. winter stadiums, cold stores, dairies). Approach of the solution corresponds with the report of the Ombudsman on the safety of winter stadiums in the Czech Republic [4].

In the preparatory phase of the project the researchers elaborated a detailed risk assessment of the Moravian-Silesian Region, including their identification and modelling of leakage of hazardous substances using software ALOHA [5] EFFECT [6] and FLUENT [7] (see Fig. 1).

Based on modelling of the effects of accidental manifestations the researchers made an assessment of environmental vulnerability of potentially endangered area. Vulnerability of the environment as a whole was assessed for the following endangered subsystems:

• population (permanent residents and intermittently residing populations)
• environment (esp. biotic environment, surface water, soil environment, hydrogeological environment)
• economic activities
• infrastructure.

Subsequently, the researchers selected major sources of risk on the territory of the Moravian-Silesian region, ie. 8 areas situated in urban areas and municipalities.

Chemical monitoring system

The most effective way to reduce risks resulting from possible accidents is to create a system enabling in case of emergency "to detect, limit the spread, monitor and warn". CHEMON system is designed and implemented in accordance with the applicable concept of protection of the Czech population [9], which is approved by the resolution of the Government of the Czech Republic.

The system includes:

• technical measures minimizing the risks directly on the sources (absorption scrubbers of ammonia in the air conditioning systems of the cooling machine rooms, spray monitors for absorption and containment of ammonia in the open air),
• system of sensors capable of indicating a dangerous concentration of hazardous substances in danger zones,
• equipment for the transmission of information to operational and information centre of the fire brigade of the Region (hereinafter referred to as "OPIS"),
• equipment for notification of significant subjects visually - by audible signalling device (educational, social and health care facilities).

CHEMON system is schematically illustrated in fig. 2.

Sprinkler systems

To reduce the concentration of ammonia leaking from the cooling engine rooms a system of absorption scrubbers (more precisely wet membrane separators "WMS") is designed, which is installed in the air conditioning and ventilation equipment of the machine rooms in enclosed buildings or sprinkler monitors at machine rooms outdoors.

In the upper part of the absorption scrubbers there is a set of sprinklers ensuring uniform spraying of filler, which ensures the fragmentation of water drops, thus allowing better washing in water. At the bottom of the absorption scrubber there is an outlet of the used liquid (ammonia water), which flows into the retention tank. Collecting of ammonia water generated by the absorption scrubbers will reduce the need to use mobile curtain branch pipes used by the emergency services, which are problematic in terms of catchment of contaminated water. Spraying is activated by a solenoid valve when the limit concentration is

Fig. 5. Position of sensors and data distribution cabinets
Rys. 5. Lokalizacja czujników i koncentratorów danych

exceeded. Diagram of the absorption scrubber can be seen in figure 3.

For outdoor accident liquidation one of the plants uses sprinkler monitors (see Fig. 4). It is a set of curtain branch pipes, which are attached to the structure by a bayonet flange. Water curtain, which can be mechanically controlled, creates a barrier in the direction to the residential area and limits the spread of toxic cloud of ammonia. Part of leaking ammonia is also absorbed by water. Sprinkling is started automatically when the preset limit concentration of ammonia is exceeded.

Data sensors and data racks

Monitoring system data sensors are used to determine the extent and intensity of the toxic cloud with output to OPIS of the Fire Rescue Squad of the region.

Detectors are placed at both the operators of the sources of risks and at selected locations in their surroundings (e.g. on lampposts, traffic sign portals, facades or roofs of buildings). Concentration limit for reporting an accident in the engine room is 150 ppm indoor and 50 ppm outdoor. The individual sensors maintain software multi-detector interdependence to eliminate false alarms.

Data distributors are designed to ensure bidirectional communication between the sensors and the user software (see Fig. 5).

Terminals for notification and information

In the dedicated facilities, which are schools, social service facilities, medical facilities or shopping centres located in the vicinity of identified sources of risk, there are terminals for notification and warning (see Fig. 6). The devices contain information on the nature of the threat and the regime rules necessary for the implementation of measures to protect people. The OPIS dispatcher can also use the terminals to transmit certain range of information to subjects.

In the event of a chemical accident, the terminal is activated via a radio network from the OPIS level of the Fire Rescue Squad of the Region. After starting optical and acoustic signalling of the terminal the screen displays information about the nature of the threat. The terminal operator confirms the acceptance of this information by means

Fig. 4. Sprinkling monitors in front of outdoor stock of ammonia
Rys. 4. Monitory spryskiwania wewnątrz magazynu amoniaku

Fig. 6. Terminal for informing and warning of population
Rys. 6. Terminal informowania i ostrzegania ludności

of a button and this information is sent back to the OPIS of Fire Rescue Squad of the Region. After confirmation, the terminal displays guidelines for staff activities on the tabs (eg. the director, teacher, janitor), whereby the staff is instructed about their obligations and the measures necessary for the protection of people of specific facility from the effects of hazardous substances. Implementation of individual steps is confirmed by the operator with a button on the terminal touch screen and thereby sending the message to OPIS. Terminals also have predefined modes for terminating the emergency, system test and exercise.

User software

User software enables communication, collection, editing and evaluating data.

Transfer infrastructure

The benefit of the system data transfer consists in the use of the existing transmission routes of unified communication and warning system, under which the Czech Republic operates terminal warning elements. Installation of sensors with data cabinets, which are terminal elements of measurement, integrated into a single notification and warning system, is one of the measures that are implemented in the spirit of the currently valid concept of protection of the population [9].

Territorial links

Implementation of the project was accompanied by media coverage and personal delivery of information to the public (e.g. information leaflets, meetings). To obtain information it was necessary to establish a "project information portal" http://chemon.hzsmsk.cz. Putting of the CHEMON project into operation was preceded by an exercise of the fire brigade of the Region.

Discussion regarding the results of the project of chemical monitoring

The CHEMON project consists in the application of the "detect, limit the spread, monitor and

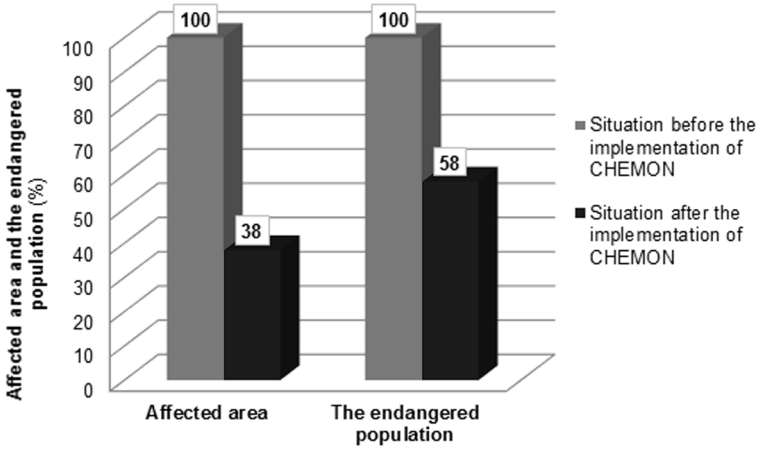

Fig. 7. Percentage reduction of the affected environment and the number of inhabitants at risk
Rys. 7. Procent zmniejszenia efektu środowiskowego oraz liczba osób narażonych na ryzyko

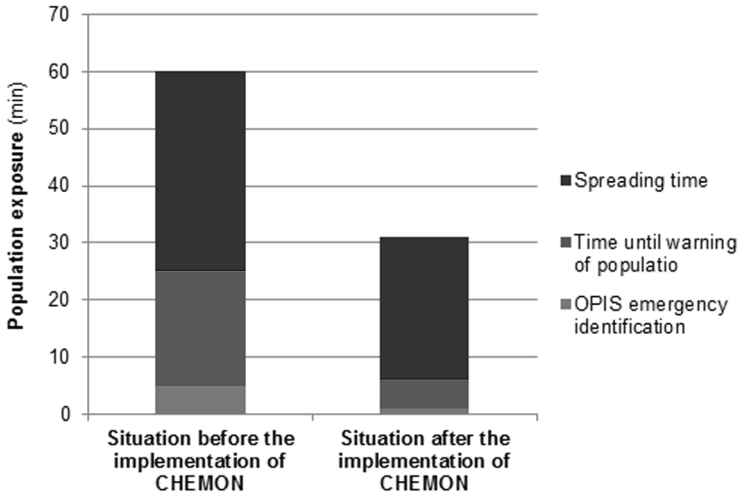

Fig. 8. Illustrative representation of reduced time of exposure of endangered population
Rys. 8. Reprezentacja graficzna zmniejszenia czasu ekspozycji na zagrożenie

warn" principle, which is the optimal form of protection of the public against exposure to hazardous chemicals. The conducted risk assessment shows that the application of these measures on selected devices will reduce the risk by one to two orders of magnitude.

The described project will reduce the area of the affected urban environment by more than half and thus proportionally decrease the amount of population at risk (see Fig. 7). Figure 7 shows the average values of 8 analyzed areas.

Practical experience gained from the exercise of emergency preparedness in the past suggests that the time to initiate the implementation of measures to protect the population in the urban environment will be reduced by up to two-thirds (blue and red area in Fig. 8).

Population exposure time, which is crucial to the degree of danger to human lives and health in the event of emergency is proportional to the time in which the emergency can be identified, initiate rescue and liquidation works, including measures to protect population (especially warning and information). The balance of timelines for individual parameters determining the duration of exposure of population implies that the time of exposure of the population endangered by toxic effects of ammonia in vulnerable areas of the urban environment is reduced by about half (blue, red and green area in Fig. 8).

Currently the whole system of chemical monitoring is in trial operation, within which organizational links and the flows of information to the involved parties are addressed. There is an ongoing "set-up" of responsibilities and obligations related

to the implementation of measures in relation to the system being built. The involvement of a large spectrum of partners who are in roles of endangered subjects is associated with high organizational requirements for effective planning and increase of the resilience of the territory as a whole.

Conclusion

CHEMON project, which is aimed to protect the population from leaks of hazardous chemicals, represents in its character and form of implementing a special system to increase the safety of the population. This project is based on the scientific principles of risk analysis, assessment of the resilience of surroundings and extensive practical experience with the implementation of safety measures. With regard to the systemic approach to chemical monitoring, notification and warning of the population and direct connections to the intervening subjects it is a project that is unique also internationally.

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Poprawa bezpieczeństwa środowiskowego dzięki Systemowi Monitoringu Chemicznego

Aby zapewnić wyższy poziom bezpieczeństwa na terenach zagrożonych wyciekiem niebezpiecznych substancji w regionie Śląsko-Morawskim, wdrożono projekt polegający na systemie monitoringu składu chemicznego – tzw. CHEMON (od ang. CHEMical MONitoring). Celem projektu jest obniżenie ryzyka potencjalnego zagrożenia ze strony niebezpiecznych substancji.

Artykuł opisuje procesy identyfikacji największych źródeł zagrożenia, możliwości i założone cele ciągłej obserwacji niebezpiecznych substancji (która nie tylko służy do informowania o zaistniałym zagrożeniu, lecz również zapewnia obserwację drogi toksycznej chmury), dostęp do istniejących ścieżek transmisji zintegrowanego systemu ostrzegania i zawiadamiania służący do alarmowania ludności, system informujący, który ostrzega ludzi przed ryzykiem występującym w ważniejszych budynkach oraz procedury zawiadamiania o wypadku – Zintegrowany System Ratunkow (Integrated Rescue System).

Słowa kluczowe: żywotność, bezpieczeństwo środowiskowe, poważny wypadek, monitoring chemiczny, ochrona ludności