Contamination of Water with Noxious and Hazardous Substances

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Summary

Surface water as well as groundwater may be contaminated with extraneous substances for various time periods. The risk of contamination increases in the vicinity of built-up areas, areas of heavy and chemical industries and extensively used agricultural land. At present, after implementing a number of preventive measures by means of legislation and by means of operational and technical means, the risk of accident and its negative effects on water supply is reduced substantially especially in the EU-27 countries. However the hazard following from different types of environmental burdens still threatens and will threaten in the next decades. Accidents caused by this hazard can endanger and endangers mainly the sources of water intended for treatment to drinking water and wells of individual users so significantly that the water becomes undrinkable, and in many cases, alternative drinking water supply has to be provided by mobile equipment subsequently for a long time. The following article outlines how to prevent and how to prepare in good time for these dangerous situations.

Keywords: water contamination, noxious substances, hazardous substances, surface water

Introduction

Water belongs to those substances in the case of which changes in composition and changes in quality occur constantly. Water very readily dissolves and, on the contrary, absorbs many substances. These are its natural properties which should always be considered. In the framework of aquatic ecosystems, the almost equilibrium state was reached during several thousand years and all consumers and users of water, fauna and flora took regular changes into account and were adapted to them. To these properties of water and changes in water, immune systems of them were adapted.

After the entry of humans into the natural cycle of water in the first half of the 19th century, the situation began to change rapidly. Various kinds of ecological threats and subsequently environmental burdens began to appear gradually. The negative situation culminated in Europe in the first half of the 20th century; nevertheless, it still exists in a large part of the world at present.

It can be stated and documented that it was water supply that was affected by human action most. Gradually, many animals dependent on the natural quality of raw water became extinct, and ingestion of water occurring in the natural environment became highly risky to humans. One of causes of this state is the low level of natural immunity of the human organism due to the long-term ingestion of only drinking water, which is preventively treated with various chemical substances.

At present, after adopting many legislative measures at pan-European as well as national level, the situation in the area of water is beginning to change markedly. In spite of that, many natural and anthropogenic hazards still threaten the natural environment and especially the aquatic ecosystems. What these hazards are and how to prevent them, or how to at least reduce their negative effects to an acceptable level, the following text outlines.

Quality of Surface Water and Groundwater in the Czech Republic

As already presented in Introduction, due to many legislative measures, a substantial change occurred in the Czech Republic when compared the situation at the end of the last century with that at the beginning of this century, namely in the case of surface water in the area of quality indicators, see Figure 1.

Despite the substantial improvements in the quality of surface water in the majority of watercourses, the situation is not, according to the standard ČSN 75 7221 classifying the quality of surface water, yet adequate to the current scientific knowledge and technical possibilities of our society. In many watercourses, sections classified into water quality Class V are there, i.e. very highly polluted water that does not allow the existence of common aquatic ecosystems under given conditions. The most frequent cause of the given classification is exceeding immission standards as a result of surface water pollution with waste water entirely non-purified or purified insufficiently. In this water, elements such as arsenic, cadmium, lead, zinc, aluminium, etc. in increased

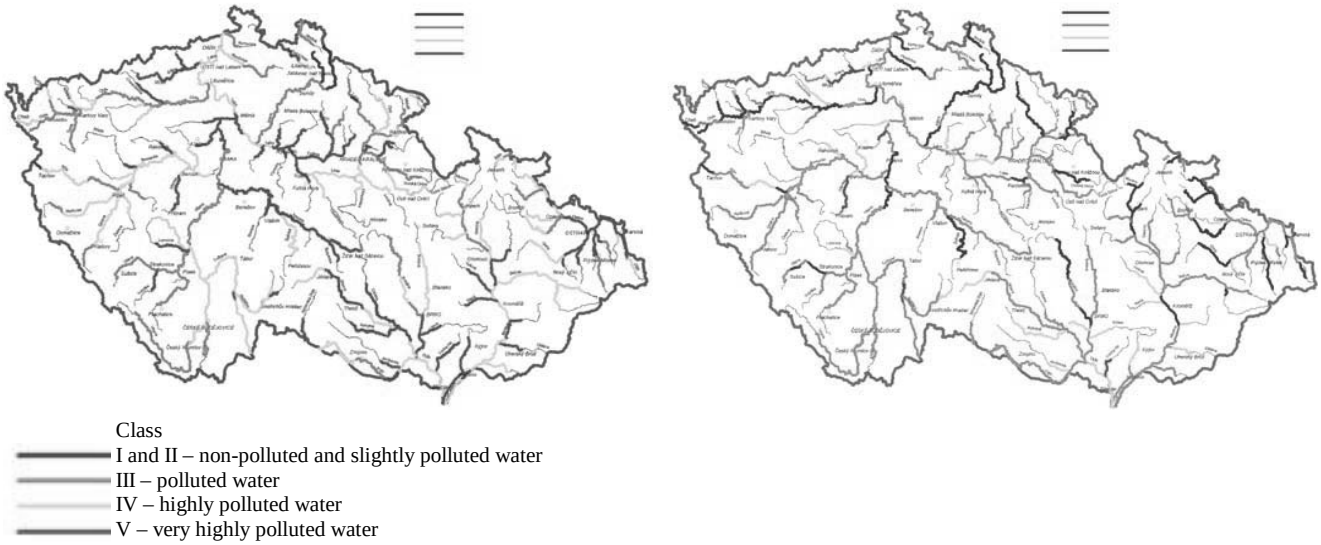

Fig.1. Comparison of improvements in surface water quality in 1991–2009 [1]

Rys. 1. Porównanie poprawy jakości wody powierzchniowej w latach 1991–2009 [1]

concentrations have been detected. Of organic substances, e.g. aliphatic chloro-derivatives and many other substances have occurred in watercourses in amounts exceeding the limits. Also pesticides coming from environmentally unsound farming are hazardous to surface water.

If surface water classified into Classes III, IV and V, and also in a broader context water in part of the river basin designed for drinking water supply, not only costs of treatment of the water increases, but in some cases, this can even be a cause that the water cannot be, although it is possible from the technical point of view, treated to drinking water standards. In the Czech Republic, drinking water can be produced merely from the water accurately classified into Classes A1, A2 and A3.

Another significant hazard to surface water is represented by various types of accidents of manufacturing equipment following from insufficient prevention and neglecting of safety measures. In almost all cases, they are needless extraordinary events. Current monitoring equipment and knowledge of risks enable each subject handling hazardous and noxious substances to take measures to eliminate accidents completely.

As for groundwater, the situation is considerably more complicated than with surface water. The quality of this water is endangered especially by farm management and old environmental burdens. Shallow groundwater is endangered by this activity more markedly than groundwater at greater depths. In spite of gradual improvement, pollution caused mainly by nitrogen substances (above all nitrates and ammonium ions), and also sulphates manifests still itself in many localities. The major hazard to groundwater consists not only in immediate pollution due to an accident, but also in long-term loading the water with these substances and their gradual washing out from the contaminated soil ground. The absolutely most serious hazard to groundwater is represented by old environmental burdens, above all unregistered landfills or landfills not technically protected against releases of noxious and hazardous substances to water-bearing layers.

Water Protection against Hazard of Contamination Caused by Hazardous and Noxious Substances

The obligation to protect surface water and groundwater against water contamination by noxious and hazardous substances follows from both the water act and the absolute necessity of protecting the environment as one indivisible part. On the environmental protection, the quality of life of future generations and their health condition and simultaneously the condition of fauna and flora generally will depend. There are always many possibilities and ways of protection and many solutions. One of them, in the field of water supply, is risk analysis and subsequently, crisis planning based on it. So that this method could achieve the expected effect and could be economically feasible, it should include the following parts:

- defining the existing and potential risks that endanger aquatic ecosystems, especially those threatened by industrial activities in individual regions of built-up areas,
- making the detailed analysis of strengths and weaknesses of the assessed system from the point of view of threats caused by noxious and hazardous substances in standard conditions and extraordinary conditions due to natural and anthro-

pogenic influences (floods, drought, events due to negligence, intentional and terrorist acts),
- assessing the potential influence of impacts on subjects of critical infrastructure in case of declaration of the state of crisis,
- incorporating the analysed hazards into crisis plans of state administration and self-governments of towns and municipalities and into crisis preparedness plans of legal and physical entities.

Of the above-mentioned four sample areas of risk assessment, owing to the space limit merely a procedure for two cases of solving the given problems will be presented in the article.

Defining the Strengths and Weaknesses of Water Supply Structures

On the basis of the analysis of potential risks threatening for various natural and anthropogenic reasons the aquatic ecosystem being assessed, the analyst defines strengths and weaknesses of the structure or the system being assessed. For instance, for a surface drinking water source the analyst determines the following:

Strengths

- low vulnerability of a water supply reservoir as a result of optimally determined sanitary protection zone and reservoir altitude,
- small risk of large-scale contamination with organic substances and inorganic substances as a result of effects of natural influences and farming, respectively,
- optimum average annual temperature of accumulated water,
- sufficient volume of accumulated water even for cases of unexpected drought lasting about 8–9 months, in relation to the water consumption curve of the water supply system,
- optimally designed withdrawal structure making it possible to react to the potentially worsened quality of water at individual levels of its accumulation, etc.

Weaknesses

- owing to a considerable distance between the water supply reservoir and the transport system and owing to ground configuration, markedly worsened conditions for the arrival of mobile fire appliances at potential places of water contamination with noxious and/or hazardous substances,
- hazard of substantial contamination of accumulated water with organic substances in case of increased timber felling in the area of south-west rim of the water supply reservoir,
- increased risk of point contamination of water in the flow into the reservoir with inorganic substances from a paper-making plant during an accident caused by an extreme flood condition,
- absence of raw water monitoring in flows from the XXX and the XZY river, with increased hazard of inflowing contaminated water during traffic accidents on a relatively heavily used mountain road in the direction of water flow into the reservoir,
- 94 percent dependence of drinking water consumption areas for about 450 000 inhabitants on raw water supplies from the source being assessed to the treatment plant, etc.

Based on defining the exhaustive amount of strengths and weaknesses of the assessed system, the analyst will obtain a basic overview of risks that endanger the given structure or the extensive system. For simplifying the solution, e.g. the method as described in Figure 2 can be used advantageously.

During task solving, a balance between individual steps and their operational and economic feasibility should not be undervalued. The underestimation or overestimation of these factors is often the cause that assumed solutions do not achieve the effect, and subsequently as examples of negation, they are given as example of counter-productive behaviour and decrease the significance of safety prevention. To reduce the risk of hazard overestimation or underestimation, the scale of relevance is to be always used, see Table 1.

If from the relevance level, very high or high vulnerability risks follow, e.g. contamination with noxious and hazardous substances that may damage the water resource or may put it out of service for a long time, it is essential not only to carry out relevant technical-safety measures but also to include this hydraulic structure in crisis plans. Hydraulic and other structures that have to be by law part of crisis planning are given in the following part of the article.

Crisis Planning and Its Importance to Dealing with Extraordinary Events

Crisis planning is of totally irreplaceable importance to dealing with extraordinary events. If common accidents, e.g. a release of noxious and hazardous substances into an aquatic environment, is to be and has to be dealt with by law especially by the culprit of the accident, then accidents negatively affecting a significant part of public infrastructure and its various strategic parts are dealt with in the context of the crisis act. For these purposes, cross-cutting and sector criteria are determined for the elements of critical infrastructure by

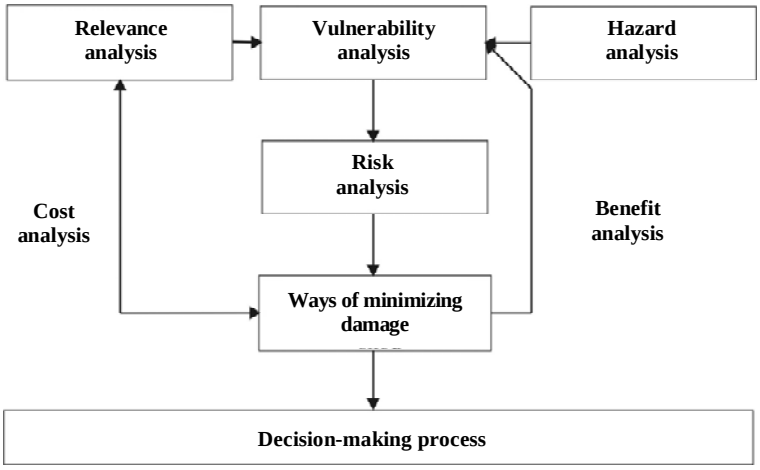

Fig. 2. Schematic diagram of risk management [2]

Rys. 2. Schemat zarządzania ryzykiem [2]

Table 1. Relevance assessment scale

Tabela 1. Skala oceny przydatności

Relevance level	
Very high	5
High	4
Medium	3
Low	2
Negligible	1

Modified according to [2]

the government decree [3]. As for the technical area of elements of critical infrastructure, it is a case of the following conditions:

Cross-cutting Criteria

- Impact on the public by limiting the provision of necessary services or another severe interference in everyday life affecting more than 125,000 people.

Sector Criteria

Sector criteria are, according to the government decree, divided into a whole series of kinds of public infrastructure. As for engineering infrastructure, the following areas are included into the critical infrastructure:

- **Energy industry** – electricity generation, transmission and distribution systems. Natural gas, including its transport and distribution systems and storage. Oil and oil products, including transport and distribution systems, fuel production and storage, with strictly defined minimum technical parameters of production units according to the type of media. It is always a case of strategic subjects that are essential for the functioning of the state,
- **Water supply** – important water supply systems supplying drinking water to more than 125,000 inhabitants, important hydraulic structures with a water capacity more than 100 million m^3, and important water treatment plants.

The above-mentioned areas of engineering infrastructure are always part and parcel of crisis plans of state administration and self-governments of towns and municipalities. Crisis plans are prepared by the following subjects:

- ministries and other administrative authorities,
- regional authorities,
- municipalities with extended competence,
- municipalities.

Subjects in the framework of preparation for crisis states always establish, among other matters, security councils, crisis staffs, and as needed, working groups of specialists for dealing with various types of extraordinary events. Working groups are of extraordinary importance especially to those areas where high specialisation and knowledge of specialists in solving the problems are necessary, e.g. for coping with events involving releases of noxious and hazardous substances into the soil environment and aquatic

ecosystems or releases of radioactive substances. The mayor of a municipality can establish, if need be, a crisis staff as a working body.

To the area of crisis management, the regional fire and rescue service is by law of extraordinary importance. In addition to other rights and duties, it organises cooperation between regional administrative authorities and municipalities in the region. In the Czech Republic, it is an irreplaceable part of crisis management owing to its permanent mobility and universal ability to cope with a wide range of extraordinary events.

Crisis plans of state authorities and autonomous bodies are in the secondary phase of planning connected with crisis preparedness plans. The subject that is responsible for the administration of a critical element of infrastructure is obliged to prepare a crisis preparedness plan. If the energy system or the water supply system consists of more independent parts, and if this is important to and reasonable for crisis management, the subject prepares crisis preparedness partial plans. The other subjects of the engineering infrastructure work out crisis preparedness plans either on demand of a relevant authority of crisis management or on the volunteer base.

Every crisis preparedness plan has to consist of the following parts and criteria:

1. **basic part**, which defines the action of a person working out the plan, extent of the action and following measures. Furthermore, brief description of the method of crisis management, overview of possible risk sources, hazard analysis and possible impact of the risks on the assessed subject and on other subjects of public and private infrastructures,
2. **operative part.** In this part has to be stated above all an overview of measures following from the crisis plan that is linked with the way of ensuring readiness for action, plan of economic mobilization measures if included in it, overview of links to relevant authorities of crisis management, and many other measures resulting from law and specific conditions of each subject,
3. **auxiliary part** contains above all an overview of legal regulations applicable in dealing with extraordinary events, overview of closed agreements to ensure the implementation of measures, principles of manipulation with the crisis preparedness plan, basic geographic data, etc.

A very important and simultaneously often neglected and underestimated part of crisis planning is the practical training of potential units and people that are able to deal with extraordinary events. Even well prepared plans will not accomplish their purposes without practical experience and specific practices concerning actions in progress. It is always necessary to take into account that the rapidity of intervention, even of preventive one, has often a decisive influence on the extent of damage. It is above all the case of releases of noxious and hazardous substances that can be efficiently eliminated merely in their initial phase. In further phases the disposal of these substances is usually not only extraordinarily difficult but also expensive.

Conclusion

It is neither realistic nor technically possible to prevent completely extraordinary events of different types and importance from occurring. In spite of many increasingly stricter regulations and measures, they happen and will happen. That is why it is desirable to be always prepared and adequately equipped to deal with them in sufficient advance. For economic reasons, it is however almost impossible so that each subject which is threatened by the occurrence of an extraordinary event may have not only a sufficient amount of various kinds of equipment but also a sufficient amount of specialists for coping with it at its disposal. Only co-ordinated activity of various brigades and units can intervene sufficiently and efficiently. Co-ordination as well as effectiveness is included in crisis preparedness in the framework of crisis planning. At present, releases of hazardous and chemical substances belong, in addition to local fires, to the most frequent extraordinary events. According to statistics kept by the Fire and Rescue Service of the Czech Republic, merely in the year 2009 5 916 such cases occurred in the Czech Republic. A trend in past years is similar and oscillates around the level of about 6 000 releases of the substances annually. With the ongoing climate changes, which manifest themselves in the world and in the Czech Republic as well especially by reducing the volume of surface water in watercourses and by lowering groundwater levels, each such event can impair very seriously aquatic ecosystems. This article outlines in an essential and brief form how to reduce the risks, to minimize the occurrence of them and to mitigate possible negative effects.

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Zanieczyszczenie wody szkodliwymi i niebezpiecznymi substancjami

Woda powierzchniowa jak i gruntowa może być zanieczyszczona substancjami obcymi w różnych okresach czasu. Ryzyko skażenia wzrasta w pobliżu obszarów zabudowanych, terenach przemysłu ciężkiego i chemicznego oraz szeroko wykorzystywanych gruntów rolnych. Obecnie po zastosowaniu szeregu środków zapobiegawczych poprzez ustawodawstwo i za pomocą środków operacyjnych i technicznych, ryzyko wypadku i jego negatywny wpływ na zaopatrzenie wodne jest istotnie zmniejszone w krajach EU-27. Jednakże zagrożenie wynikające z różnych form obciążania środowiska nadal mu zagraża i będzie zagrażać przez najbliższe dziesięciolecia. Wypadki spowodowane przez to niebezpieczeństwo mogą zagrażać i zagrażają głównie źródłom wody przeznaczonym do oczyszczania w celu uzyskania wody pitnej oraz studniom pojedynczych użytkowników w sposób tak znaczny, że woda staje się niezdatna do picia, a w wielu przypadkach, należy zapewnić alternatywne źródło wody poprzez jej mobilny transport przez dłuższy okres czasu. Poniższy artykuł opisuje w jaki sposób zapobiegać i jak się dobrze przygotować na niebezpieczne okoliczności.

Słowa kluczowe: zanieczyszczenie wody, substancje szkodliwe, substancje niebezpieczne, wody powierzchniowe