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Preparedness for crisis situations in drinking water supply

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Abstract

Looking at our planet, we can think that there is no necessity to save water. Over 70 % of Earth´s surface is water-covered. But we need fresh water that is consumed across all sectors of society. The amount of drinking water on Earth is small and most of it is locked for human consumption in the icecaps or located deep beneath the surface. So there is little water left (about 0,007 % of all water in the world) for direct human use. Due to extensive development of infrastructure in recent years we have brought water to our homes and become fully dependent on functional water supply system. 60 % of the world´s population will live in cities in 2020. Such urbanization will increase pressure on infrastructure functionality in any situation. When the system is interrupted, mostly whole society is paralyzed. Resilient water system and preparedness of the authorities responsible for responding to extraordinary situations in drinking water supply is fundamental condition to ensure state security and population protection. The paper presents first results of research project VF20102014009 "The safety assessment of critical infrastructure elements and alternative possibilities for increasing the security of cities and municipalities in the drinking water in case of major natural disasters and industrial accidents". The project was being solved within Security Research of Ministry of the Interior of the Czech Republic in 2010 – 2014.

Keywords: water supply system, critical infrastructure, hazards identification, critical elements

1. Introduction

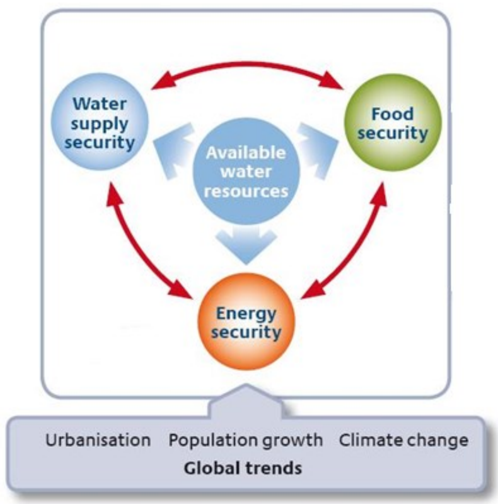
Due to growing population, modern life that is very water intensive, and due to environmental degradation, water has become one of the scarcest goods on Earth. The question how to ensure sufficient amount of water has gradually become key interest of world organizations. The issue is a topic of various research projects and integral part of scenarios for the future. World water day reminds us importance of preserving water resources on 22nd March that has been world water day since 1993 and associated with numbers of campaigns.

Water is critical source mainly because it meets our fundamental (physiological) human needs. Basic needs contain also food requirements and needs for heat essential for our survival. In view of ensuring functional society, physiological needs together with need for safety represent the highest priority. Only if basic needs are satisfied, then we can turn our energy towards "higher" needs leading to development of a person and thus the whole community. This idea is known as

Maslow´s hierarchy of needs, defined by American psychologist Abraham H. Maslow in 1943 [1].

Within cities, life support services are provided via infrastructure. Despite the fact we can find differences in definitions across countries, sectors essential to maintenance of vital social functions, security and economic are always called "critical infrastructure". In the Czech Republic there are nine critical infrastructure sectors. The first three systems ensure physiological human needs: 1. Energy, 2. Water management, 3. Food and agriculture [2]. The society must develop critical infrastructure and at the same time increase its resilience including preventive protection in order to meet basic needs in every situations. In view of the fact that population protection is one of primary tasks of government, it is crucial to ensure water supply, food and energy security in normal state, as well as during emergencies and crisis situations. Water resources play a significant input into all key systems of security (water – food – energy). These systems are highly interdepended and their links are strengthened by global trends such as urbanisation, population growth, and climate change (see Figure 1).

Figure 1: Water – Food – Energy nexus



Source: [3]

2. Global trends and resilient society

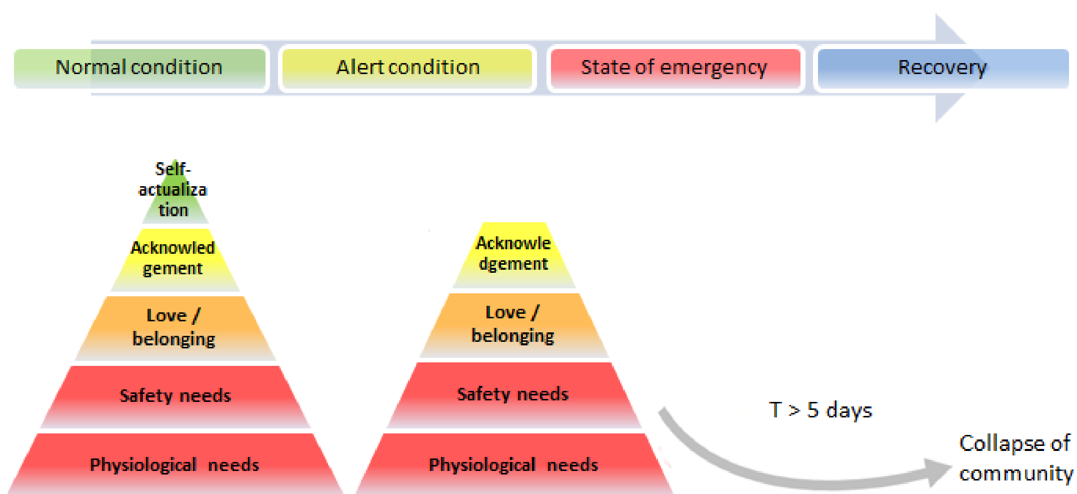
Less than half the current population lived on Earth 50 years ago [4]. According to current projections, the world population will reach 9 billion by 2050. Such a population explosion means huge pressure on vital resources. The reduction of resources causes number of security threats, including civil disorders and conflicts. Current agriculture is the dominant water user (70 % of global water withdrawals go to irrigation). In the future agriculture consumption of water will be even greater because of growing demand for food and increasing standard of living. Higher economic standard change food habits – consumption of meat and livestock products continue to rise. Producing livestock products takes about 10 times more water than crop production. Higher meat consumption also means that more crops have to be grown for feeding livestock. Any extra feed crops require additional amount of water. Irrigation and sufficient water resources is thus a key factor to ensure food security in many parts of the world.

We can observe similar trend in energy sector that is necessary for the production of both food production and distribution of drinking water. All sources of energy and electricity require water during its life cycle, from phase of fuel extraction, growing biofuel crops to generation. According Energy Information Administration global energy consumption is predicted to increase about 49 % from 2007 to 2035. The largest growth will most likely be seen in Africa, severely challenging the ability to provide the water required to produce the necessary amounts of energy as this sector competes with water for food and sanitation [5].

The population growth is related to physical expansion of conurbations. Traditional rural life disappears and modern society migrates to big cities that offer more comfortable way of life. In 1950, there were only two mega-cities with population exceeding 10 million: New York and Tokio. Already in two years (2015), it is projected that there will be 23 such cities, most of them will occur in developing countries [6]. Cities represent concentrated centres of people, assets and economic activity. This concentration increases exposure to the impacts of natural disasters and industry accidents, making urban dwellers particularly vulnerable. With rapid urbanization, cities have to try harder to meet the basic needs of their growing populations. Functional infrastructure is essential condition of life in cities. When a disaster hits, impacts can include the loss of basic services, damage or destruction of homes, reduction or loss of livelihoods, threats to food security, and the rapid spread of malnutrition and water-borne diseases [7].

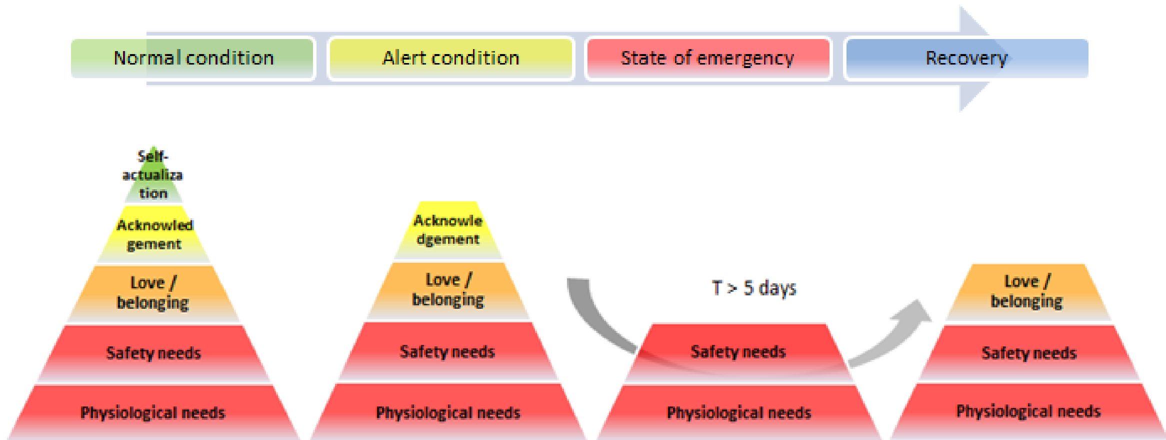
Vulnerability of city is related not only with its size but mainly with duration of interruption of critical infrastructure ensuring basic human needs. Based on experience of short-term and long-term disasters, in view of security aspects, events are trouble if the society cannot recover physiological and safety needs in few days. After 5th day the collapse of community will certainly come (see Figure 2). On the other hand (see Figure 3), community with high level of resilience and preparedness to long-term extraordinary events can avoid its breakdown [8].

Figure 2: Vulnerability of community during a long term extraordinary event



Source: [8]

Figure 3: Resilience of community for long-term extraordinary event



Source: [8]

From the above text it is quite evident how important public water supply is not only within framework of critical infrastructure. Breaking continuity of water supply has negative effects on providing medical care, food and agriculture sector, industry and energy sector, and especially on the primary user – every resident. The objective of the project "The safety assessment of critical infrastructure elements and alternative possibilities for increasing the security of cities and municipalities in the drinking water in case of major natural disasters and industrial accidents" is to develop a systematic approach to critical infrastructure protection in field of drinking water supply and suggest general approach to risk reduction.

3. Risk assessment of drinking water supply system

The research project is being dealt with holistic attitude "catchment to tape". It means assessment of all potential threats and risks to the entire system of drinking water supply system – from source (catchment basin, wells) to tap (distribution to consumers). The research team consists of experts to protection and safety of critical infrastructure, water treatment system and water management systems. The specialists deal with extraordinary events with potential to cause malfunction of drinking water supply system for more than 24 hours, either in quantitative or qualitative point of view. Such events can easily escalate into crisis situation and to become an interest of crisis managers. Good preparedness of authorities responsible for responding to emergencies, operators of water supply, and efficient co-operation between them is fundamental condition to manage crisis situation.

Preparedness of operators and emergency management authorities to crisis situation is proclaimed by crisis preparedness plan and crisis plan of municipality, respectively region, in the Czech Republic. The subjects of critical infrastructure (water supply operators) must develop crisis preparedness plan and municipalities (regions) must prepare crisis plan according to basic legislative regulation of crisis management – Act No. 240/2000 Coll. on crisis management. Crisis preparedness plan has to contain risk analysis where the operator considers relevant threat scenarios in order to assess vulnerability and potential impact on function of critical infrastructure elements. However, legal regulations do not suggest specific way of analysis or how detailed assessment should be. Based on results of risk analysis, the operator can specify priorities in risk management so quality of risk assessment determines level of operator´s preparedness to crisis situation. In this respect, the objective of research team is to offer operators of drinking water supply an algorithm of risk assessment of water management systems. Relevant outputs of risk analysis should help to increase resilience of the system as well as to improve preparation of emergency management authorities (especially Fire Rescue Service[1]) for extraordinary events related to ensuring potable water supply for dwellers.

The basic step of any risk analysis is description of evaluated system and identification of key assets and threats. Every drinking water supply system can be divided into three subsystems (source water system, water treatment system, distribution networks) and within them it is possible to identify irreplaceable (critical) elements. If these elements do not work or they are damaged, water quality and/or quantity can be influenced in negative way. On the basis of detailed analysis of water supply system, research team has identified 16 critical elements of the system (AT1 – AT16). It is possible to create a model of each drinking water supply system from these elements, according to the occurrence in the Czech Republic. Next, relevant threats can be matched to the identified elements. Experts compiled a list of potentially possible threats in the Czech Republic for each single critical element. Hazards impact selected element directly and thus they pose danger for whole drinking water supply system. Extraordinary events were sorted into four categories – Natural, Human, Technological, and "Dependence" – the last category includes secondary effects of failures of other infrastructures that threaten elements indirectly as a result of interdependence - for example: blackout because of floods, storms, frost or another disaster [9].

The following Figure 4 shows an overview of all identified natural hazards and determination which critical element is affected by particular threat. Colours reflect risk indexes and so weaknesses of the model of drinking water supply system. The red colour represents the elements with the highest risk index – unacceptable risk, the yellow means conditionally acceptable risk, and acceptable risk is the green colour.

[1] Fire Rescue Service (FRS) is leading coordinator of Emergency services of Integrated Rescue System (IRS) and guarantor of population protection in the Czech Republic (CR). IRS is determined for co-operation of rescue and clean-up operations in case, where a situation requires operation of forces and means of several bodies. Basic IRS bodies are FRS of CR, Police of CR and Medical Rescue Service.

Figure 4: Natural threats in drinking water supply

THREATS	CRITICAL ELEMENTS															
	Source water systems							Water treatment systems					Distribution networks			
NATURAL THREATS	AT1	AT2	AT3	AT4	AT5	AT6	AT7	AT8	AT9	AT10	AT11	AT12	AT13	AT14	AT15	AT16
Earthquake	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Drought	x	x	x	x		x	x									
Flood	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
High temperature		x	x							x						
Frost				x			x	x	x		x	x	x	x	x	x
Toxic			x													
Increased solid content in the water			x													
Sediments				x	x											
Lightning				x	x		x	x	x	x	x	x	x	x		
Gale				x	x		x		x							
Snow				x	x		x		x							
Landslide				x	x		x	x	x		x				x	x
Wind					x		x				x	x	x			
Air contamination of the water								x								
Fire								x	x							

Source: own compilation

The risk assessment helps to detect weaknesses of water supply system. Except of that, the evaluating process includes assessment of other factors such as: existence of likelihood or consequence reduction measures, the nature of impacts on consumers (qualitative and quantitative effects), design of appropriate measures to increase resilience of weaknesses in the system, assessment of the territorial impact, and the necessity to involve Integrated Rescue System (Fire Rescue Service) into managing crisis situation. Operator of drinking water supply system should know for each such a situation if he is able to manage it of his own forces and means, or if he requires assistance of FRS (services, equipment). This information can especially help to improve the level of preparation of emergency management authorities to respond to disasters and increase population protection. Sharing relevant results from the risk assessment of drinking water supply system is basic condition for setting co-operation between private sector (operators) and public sector (emergency management authorities, FRS) during crisis situations related with potable water supply.

4. Material and methods

Failure Mode and Effects Analysis (FMEA) together with What-If Analysis and brainstorming were used to identify the critical elements. The identification was realized during regular expert meetings. Risk index (IR = Likelihood * Impact) was determined thanks to expert estimation of possibility of hazards (Likelihood), and method Fuzzy Logic and verbal statements was used to estimate hazard consequences (Impact).

5. Conclusion

The issue of continuity of life supporting supplies escalates due to global changes and weather extremes that are growing more frequent and intense (floods, hurricanes, earthquake, drought, etc.). Modern society, which is characterized by strong dependence on infrastructure, has to deal with issues of keeping its basic functions, improving level of prevention, preparedness, and managing consequences of emergencies.

Water as a basic condition for life, ensuring economic growth of society and national security, plays a crucial role in area of critical infrastructure. Partial or complete interruption of water distribution could paralyze life in the territory or even functions of the state in case of large-scale interruption of water supply. Water management infrastructure is a complex system, vulnerable to a wide range of threats. Risk analysis is the basic tool for increasing resilience of drinking water supply because it enables early detection of "Achilles´ heel" in the system, the operator can determine the priorities in risk management and take necessary measures for increasing his level of preparedness for crisis situations. Both private and public sector must be engaged in disaster recovery thus preparation phase should involve description of the organizational cooperation between the operator and the emergency management authorities responsible for managing crisis situations related to water supply.

The article summarizes results of the research project from task focused on analysis and risk quantification of drinking water supply. In the following period, the research team will deal with development and improving of risk assessment algorithm and completion of project outputs - methodical instruction intended not only for operators of water supply systems but especially for Fire Rescue Service and emergency management authorities.

Acknowledgement

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In the paper there are pieces of information used in research project VF20112015018 "Security of population – crisis management" (AF-CITYPLAN is participant on the project).

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