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SELECTED PROBLEMS OF WATER SUPPLY SAFETY

Municipal water supply system operation is connected with potential health risks for water consumers. This risk is directly proportional to the probability of the appearance of undesirable events, and inversely proportional to the methods of water supply system protection. In this work, basic definitions connected with health risk analysis and assessment have been presented. The categories of harmful chemical substances that can have a negative influence on human health as a result of drinking polluted water have been given. A method for risk management has been developed, taking into account social attitude towards hygienic and sanitary conditions. Quantitative limits of risk connected with poor-quality drinking water have also been proposed.

1. INTRODUCTION

Municipal water supply system (WSS) operation, from the point of view of both producer (waterworks) and consumer, is constantly connected with risk. Risk has accompanied various human activities since the past history. The modern concept of risk has its source in the Indo-Arabic decimal number system, which spread to Europe only eight hundred years ago. The ubiquity of risk in social and economic life caused this notion to become a subject of studies in many scientific disciplines [4]. A universal definition of risk has yet to be provided. The greatest contributions to modern understanding of risk are Americans [1]. The first scientific definition of risk was offered in 1901 by H. Willet in his work *The Economic Theory of Risk and Insurance*, in which he described risk as something objective connected with subjective uncertainty. F.H. Knight, however, in his 1921 work *Risk Uncertainty and Profit* presented his concept of measurable and non-measurable uncertainty. Measurable kinds of uncertainty he called *risk* and non-measurable kinds he called *uncertainty* in a strict sense [1]. Nowadays, in technical science, the following definition is obligatory [6], [7]:

Risk (r) is an arranged four-element set:

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$$r = (S_i, P_{Si}, C_{Si}, O_{Si}). \tag{1}$$

The formula to determine the measure of risk is the following:

$$r = \frac{P_{Si} \cdot C_{Si}}{O_{Si}}, \tag{2}$$

where:

S_i – representative failure scenario i described as a series of successive undesirable events,

P_{Si} – point weight connected with the probability that the i representative failure scenario S_i will appear,

C_{Si} – point weight connected with the size of loss caused by the i representative failure scenario S_i,

O_{Si} – point weight connected with the WSS protection against the i representative failure scenario S_i (protection barriers, clean water tanks, system monitoring, etc).

Danger and hazard are the factors that determine the magnitude of risk. Danger is considered a cause of loss. It is characterized by some kind of arranged time sequence of successive phases. In the first phase, an appearing threat creates danger (e.g. an incidental water pollution in the source). In the second phase, danger becomes real (e.g. polluted water appears in the distribution subsystem). In the third phase, the effects of real danger are revealed (e.g. water consumers' gastric problems). Hazard is identified as a set of conditions and factors that have a direct impact on the second phase of danger. The severity of any given danger is fundamentally based on hazard. Hazard as a risk factor determines the magnitude of loss resulting from risk realisation [6].

2. SELECTED DEFINITIONS RELATED TO HEALTH RISK ANALYSIS AND ASSESSMENT

To analyse and assess the health risk of water consumers, one has to assume suitable definitions [2], [5]:

- Acceptable daily intake (ADI), the quantity of a chemical substance which can be consumed during any given day.
- Reference dose (RFD), the concentration of daily consumption that should not cause significant risk of adverse effects.
- Uptake dose, the quantity of a chemical substance consumed from water.
- Route of exposure, a place where a toxic substance is absorbed by the human organism.

We can distinguish between alimentary, respiratory and skin routes:

- Adverse effect, irreversible biological change appearing during exposure or after, which can also make the human organism more sensitive to other factors.

• Lowest observed effect level (LOEL), the lowest level of dose at which one can observe the occurrence of statistically significant increase in the frequency of adverse effects in the exposed group, in comparison with the control group.

• Exposure, as related to risk assessment, it is a process during which chemical, biological or physical substances, whose quantity can be determined, enter the human organism.

• Risk assessment, a process of identification and quantitative risk assessment, based on data on the occurrence of adverse factors. It is a four-stage process that consists of threat identification, assessment of dose-response relationships, exposure assessment and risk characterisation.

• No observed effect level (NOEL), the highest dose level (exposure) at which we cannot observe any statistically significant increase in the frequency of effects in the exposed group in comparison with the control group.

• No effect level (NEL), the highest dose of substance which does not cause any detectable pathological changes in the specific conditions.

• No observed adverse effect level (NOAEL), the highest dose level (exposure) at which we cannot observe any statistically significant increase in the effect frequency or the effect intensity in the exposed group in comparison with the control group.

• Threshold of specific effect, the lowest dose or concentration of the chemical substance causing changes in the organism that exceed physiological adaptation possibilities.

• Dose–response relationships, relationship between dose or the chemical substance concentration and the probability of the occurrence of a specific negative health effect in the exposed population.

3. IMPORTANCE OF WATER SUPPLY SAFETY FOR CUSTOMER AND WSS OPERATOR

The safety of the water supply is connected with the delivery reliability and the stability of drinking water quality, according to the relevant standards and acceptable prices. Table 1 presents the factors influencing water supply safety from a recipient's point of view.

Table 1

Water supply safety from a recipient's point of view

Safety of drinking water consumers	
External factors	Internal factors
Continuity of supply in a required quantity Standard quality Acceptable price	Favourable terms of contract with the supplier Care for installation, fittings and devices

For the WSS operator, safety is directly connected with the continuity of water supply to the distribution subsystem, the adaptation of water sources to recipients' unequal water consumption and such a way of performing system operation which guarantees reliability. The WSS reliability is ensured by: correct designs; high quality and durability of water-pipes, pumps and water treatment equipment; constant monitoring according to relevant procedures; response speed in control of action; as well as efficiency in the repair of failure. An important factor in WSS operation reliability is having the right water subsystem configuration and a diversity of entry points for water sources. Table 2 lists the factors responsible for the water supply safety from the WSS operator's point of view.

Table 2

Water supply safety from WSS operator's point of view

WSS safety from operator's point of view
Continuity of water supply Adaptation of water sources to meet unequal demand for water Technological reliability and work flexibility Management of risk connected with system operation

4. RISK MANAGEMENT

$$\text{Expert risk} - \text{risk} = \frac{\text{probability} \times \text{effects}}{\text{protection}},$$

$$\text{social risk} - \text{risk} = \text{threat} \times \text{vulnerability},$$

$$\text{vulnerability} = \frac{\text{sensitivity}}{\text{resistance}}, \text{ so as a result risk} = \frac{\text{threat} \times \text{sensitivity}}{\text{resistance}}.$$

As far as public safety is concerned, every level of state administration has a specific mission [3]. The role of safety systems is to prevent undesirable events. However, historical analysis of major failures shows that there are no perfect safety systems and the appearance of undesirable events stimulates system development [4]. This apparent paradox favours the progress of safety systems whose task is to eliminate not only recognised undesirable events, but also those events that are predicted in failure scenarios. Preventing these events allows agencies to fulfill their assigned public missions. The public authority on every level of state administration has a duty to warn citizens about threats in their area, which is connected with conveying reliable information about risk. Access to information about safety is one of the basic rights of citizens. Everyone has the right to express their opinion on their own safety, regardless of an expert's assessment. The right to information is in some ways a guarantor of action aiming to reduce risk connected with undesirable events.

In relation to the response phase, one can distinguish four levels, depending on the magnitude of the consequences resulting from the undesirable events: routine undesirable events – emergency action of rescue services, extraordinary situations – coordination of action at the local level, crisis – actions supported by higher level authorities, state of emergency – management by state authorities.

A gradation of social attitude to hygienic and sanitary situations is shown in figure 1.

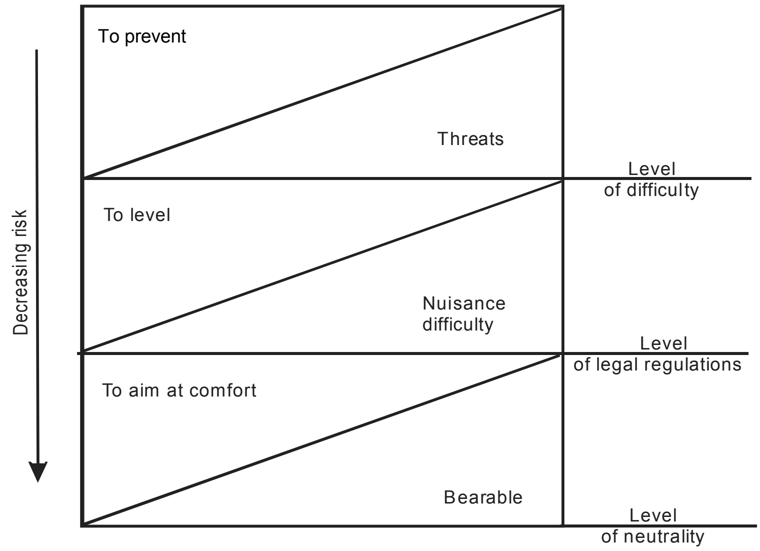

Fig. 1. Social attitude to hygienic and sanitary situations

Table 3

Quantitative and qualitative limits of risk connected with poor drinking water quality in public supply systems, related to one year

Consequence category	Description of consequences	Tolerable risk	Controlled risk	Unacceptable risk
Insignificant	Incidental difficulties that are not a threat to health, lack of consumers complaints	$<10^{-3}$	$10^{-1}\div10^{-3}$	$>10^{-1}$
Marginal	Perceptible organoleptic changes, individual consumer complaints	$<10^{-4}$	$10^{-2}\div10^{-4}$	$>10^{-2}$
Significant	Organoleptic changes are significant, numerous consumers complaints, reports in local media, water can be used after 10-minute boiling	$<10^{-5}$	$10^{-3}\div10^{-5}$	$>10^{-3}$
Serious	Mass gastric problems, relevant sanitary inspector turns off water pipe, toxic effects in pollution indicators, large number of reports in local media, general information in national media	$<10^{-6}$	$10^{-4}\div10^{-6}$	$>10^{-4}$
Catastrophic	Mass hospitalisation as a result of health complications, deaths, front news in national media	$<10^{-7}$	$10^{-5}\div10^{-7}$	$>10^{-5}$

Table 3 presents quantitative and qualitative categories of the consequences connected with the three-level risk gradation.

5. CONCLUSIONS

• Risk grows as the level of threat increases. According to the "ergo-dynamic rule", if failure is possible, the probability of its appearance approaches one (event is certain) when the time of expectancy approaches infinity.

• Safety procedures in the present WSS are distinguished by the fact that risk reduction is made by technical means as well as by the organizational means.

• Analyses of major failures that happened in the WSS in previous years show that their causes derive from all stages of system existence – errors in assumptions, errors in design, errors made during construction, start up and exploitation, as well as those resulting from repairs and modernisation.

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WYBRANE ZAGADNIENIA BEZPIECZEŃSTWA DOSTAWY WODY

Funkcjonowanie wodociągu publicznego wiąże się z ryzykiem zdrowotnym konsumentów wody. Ryzyko jest wprost proporcjonalne do prawdopodobieństwa zajścia zdarzenia niepożądanego i strat z nim związanych oraz odwrotnie proporcjonalne do metod ochrony systemu zaopatrzenia w wodę. Przedstawiono podstawowe definicje związane z analizą i oceną ryzyka zdrowotnego. Podano kategorie substancji chemicznych, które mogą negatywnie oddziaływać na zdrowie człowieka, który pije skażoną wodę. Opracowano metodę zarządzania ryzykiem, uwzględniając warunki higieniczno-sanitarne odpowiadające odczuciom społecznym. Zaproponowano ilościowe granice ryzyka związanego ze złą jakością wody do spożycia.