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Sustainability and specifics of fire water sources in new climatic conditions using the example of the Czech Republic

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Abstract

Sufficient fire water for fire protection of an area is of fundamental importance in the security of the state and its infrastructure. Fires cannot be completely prevented, but the consequent damages can be minimized provided that there are enough extinguishing agents to eliminate them. The main and most important current and future extinguishing agent is water. Due to the fact that climate change is ongoing, it can be assumed that many existing natural and multipurpose sources of fire water may not meet the capacity requirements for firefighting, or they will not be available at all. The aim of the scientific approach is to evaluate and specify the availability of fire water in the new climatic conditions using the example of the Czech Republic. Another aim of the article is to characterize the possible shortage of fire water and to propose means by which the maximum effect can be achieved with minimum investment costs, and to ensure the long-term sustainability of natural and multipurpose fire water sources. The analysis of strengths and weaknesses, opportunities and threats was used for the evaluation of the availability of fire water in new climatic conditions. It arises from the results of the article and its broader concept that, despite the current satisfactory situation in fire protection in the Czech Republic regarding fire water, the risks of its shortage are increasing when the climate changes significantly. The lack of fire water will not be nationwide, but most likely only regional.

Keywords Aquatic ecosystem · Climate change · Fire water · Safety risk · Risk elimination · Risk analysis methods

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1 Introduction

The climatic conditions of individual states or regions are not an unchanging quantity—they tend to change over time from natural, and currently also anthropogenic causes. Since the beginning of the 21st century, one of these changes has been taking place worldwide, which, among other things, will also affect the aquatic ecosystems of the Czech Republic (Brumar et al., 2018; Dušek, 2015). Development trends suggest that natural volumes of surface and groundwater are most likely to be significantly reduced in the coming years and decades. In many regions in the Czech Republic, smaller recipients of watercourses and groundwater reserves will be significantly endangered (Walmsley, 2020). If artificial water accumulations cannot be operatively managed and adequately replenished depending on snow and rainfall, then running water and groundwater will be at risk of at least a periodic shortage. However, a large part of this type of aquatic ecosystems is used for public water supply purposes and for fire safety of an area, and in many cases as the only source of fire water.

Adverse processes that limit and reshape water resources can generally be caused by either natural or human origins, or a combination of both (Garnier et al., 2015; Sivakumar, 2011; Quevauviller, 2010, 2011). These natural and artificial processes that negatively affect climate include the inclination of the Earth's axis, the intensity of solar radiation, changes in plate tectonics and volcanic eruptions, increasing concentrations of greenhouse gases, declining land, shelf and mountain glaciers and increasing sea levels. (Intergovernmental Panel on Climate Change, 2013). The changes in climate conditions, which may not be caused directly by or related to human activity, may nevertheless negatively alter the spatial and temporal distribution of water resources. As a result, water resources are not evenly distributed throughout the world (Richey et al., 2015). For example, purely human causes include the growing world population (Information and External Relations Division of UNFPA and the United Nations Population Fund, 2015), which brings with it an increasing rate of urbanization (United Nations, 2014) and an increasing number of developed areas throughout the world. Two negative trends are also closely associated with these causes. The first is called Urban Sprawl (Eigenbrod et al., 2011), where commercial, logistics, industrial and other businesses are spread around cities in so-called green meadows, and the second is called Urban Sealing, where all types of construction lead to the conversion of natural permeable surfaces to impermeable surfaces (Šerek, 2014). Additionally, increasing commercial deforestation and global environmental pollution (Sivakumar, 2011), with which is also associated the pollution of the world's oceans (Halpern et al., 2015; Lützhøft et al., 2012) and rivers (Greenpeace International, 2011; Lofrano et al., 2015; Pistocchi et al., 2012). In many countries, rivers, oceans and lakes can be the only source of both drinking and fire water.

As is evident from the aforementioned, water resources—not only for fire protection purposes—face increasing pressures to meet the social, economic and environmental needs of the growing world population (United Nations World Water Assessment Program, 2015). These resource constraints bring with them certain restrictions on water resources or cause their complete absence in some areas. Developed areas that do not have access to natural water resources are dependent on drawing this water from other sources, often from multipurpose sources. It is a multipurpose water source that, in addition to its primary purpose, also serves firefighting purposes, such as water dams, water reservoirs for industrial and economic use, sewage treatment tanks, public water supply and storage reservoirs, swimming pools and canals. However, this often happens even in cases where developed areas have access to natural resources. This model is increasingly applied by both the public and private sectors, without any admission that the model is monotonous, and thus that other resources are being eliminated.

In recent years, management of water resources has been considered an interesting subject, specifically because of the pressure on the natural system in order to obtain better quality water (Loukas et al., 2007). Decision-making problems for water resource management often encounter various conflicting criteria, because it is necessary to address technical, environmental and social consequences of water resources, along with economic criteria, in order to make reliable decisions and achieve appropriate decision-making results (Zarghami & Szidarovszky, 2009). It is this multi-criteria decision nature that makes the water resources area very favourable for the application of multi-criteria decision-making (Hajkowicz & Higgins, 2008). Multicriteria decision-making methods are very powerful tools that are often used to evaluate and select problems involving several, usually conflicting, criteria (Hashemi et al., 2013).

Climate change is reflected both in water management and in the close connection between agriculture and land management. If the balance is disturbed, for example, through inappropriate tillage, the risk of an erosive environment increases, particularly during periods of heavy rainfall. For this reason, the relationship between soil and water is completely dominant in maintaining the soil moisture regime in current and future conditions. However, these conditions are variable over time. The periods alternate between dry—tempudick periods, with moist soil-climatic regimes—sub-humid, udick and perudick. At present, it can already be statistically recognized that drier soil and climate regimes are beginning to predominate (Trnka et al., 2013). This trend constitutes a serious threat to aquatic ecosystems and, more broadly, to the overall current environment.

In the Czech Republic, the predominant part of the territory has a low ability to accumulate a sufficient amount of rainwater. One of the main causes of this condition is hydrogeological structures, with a relatively lower thickness of sandstones suitable for the accumulation of rainwater in the soil environment. The average precipitation in the Czech Republic is 680 mm. In many places, however, the annual total precipitation is only about 410 mm of precipitation. The lack of precipitation and the change in its distribution over time, together with improperly implemented water bodies in the last century, fundamentally change the groundwater reserves in the region. This fact is also confirmed by the outputs from the measurement and evaluation of balance values, from exploratory and observation groundwater wells, carried out, for example, by the T. G. Masaryk Water Research Institute (T. G. Masaryk Water Research Institute, 2021) and the Czech Hydrometeorological Institute. With the expected climate change, without the adoption of additional technical and safety measures, there will be a need to change the approach to water management and land management in agriculture, forestry and urban development. However, this is not only a regional threat to one or to a group of states, but is rather a global issue, and therefore the solution must be the subject of negotiations of international expert teams.

The aim of the scientific approach is the professional evaluation and specification of the availability of fire water in new climatic conditions using the example of the Czech Republic. Another aim of the article is to characterize the possible shortage of fire water and to propose means by which the maximum effect can be achieved with minimum investment costs, and to ensure the long-term sustainability of natural and multipurpose sources of fire water. Two research questions were formulated based on the set goals:

A. What is the availability of fire water in the new climatic conditions in the Czech Republic and how can this availability be assessed on the basis of a scientific approach?
B. What are the possible cases of fire water shortage in the new climatic conditions and how can the long-term sustainability of natural and multipurpose fire water sources be ensured?

2 Methodology

From the hydrological perspective, compared to other countries, the Czech Republic has relatively small reserves of raw water for various purposes, including use for fire protection of an area. The state administration is also aware of this situation and therefore, as part of the cycle of long-term sustainability of European waters, it is involved in international cooperation of European Union countries in the water management process (Fig. 1).

The process of long-term sustainability of the quality and quantity of surface or groundwater of aquatic ecosystems must never be closed off (Krajewska et al., 2021). In order to be able to deal with this issue, particularly in the coming climatic conditions, the situation will also depend on the preservation of natural sources of fire water for the majority of the Czech Republic. These are mainly undeveloped areas in the country without a real possibility of using multipurpose sources of fire water from the water supply systems of cities and municipalities, or water supply systems of a supra-regional nature. The threat of fire water shortages will primarily increase as the intensity of climate change increases, causing an increase in risk, all the way to crisis situations.

The risk of a lack of fire water for firefighting is usually gradual and may not always raise serious concerns. However, the professional public must always perceive the full range of indications and potential threats posed by climate change. The main signals that pose a real threat to safety engineering specialists include the following three factors:

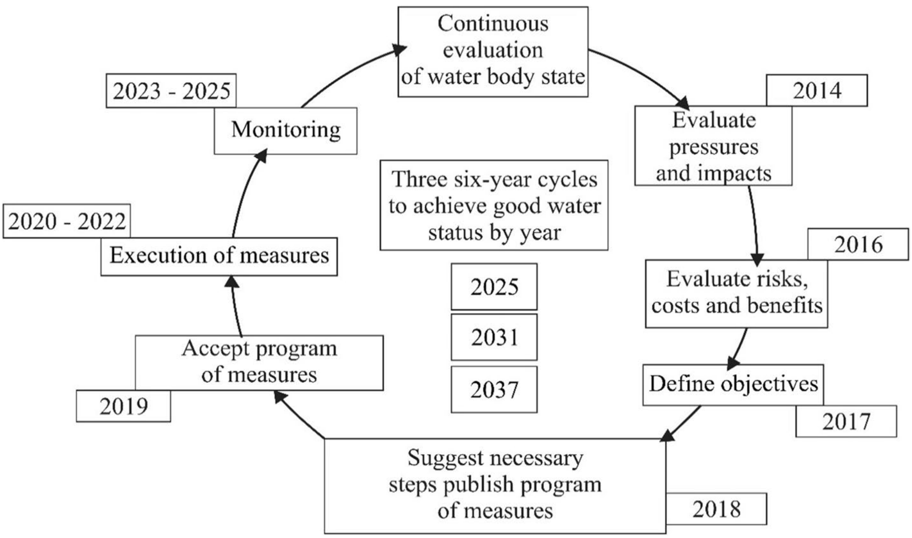

Fig. 1 The process of significantly improving the quality and quantity of European waters (Water Management Association in the Czech Republic, 2019)

(a) regular deviations of long-term precipitation conditions in the monitored river basin or region,
(b) decreasing volumes of flowing water in small recipients - permanently or in the short term,
(c) reducing the yield of shallow groundwater, which is often a backup source of fire water in undeveloped territories.

The outputs from the aforementioned factors and many others almost always indicate a serious emerging long-term problem that needs to be addressed methodologically well in advance.

In order to achieve the goals and documents for the research question, a system approach to the literature research was used in order to obtain available information sources, published results and information in the field of fire water availability in new climatic conditions. Furthermore, the analysis and synthesis method was used. This involves the division of the whole into components and the connection of partial information into the whole, and a description of the principles in interdependencies. This procedure was used in the analysis of current information, particularly in their synthesis in the final part of the research. One of the methods for elaborating the goal of the research was deduction. It is the process of reasoning from premises, when a conclusion is reached on the basis of evidence. The procedure was applied in the processing of the findings of the empirical survey to the overall final part of the research.

The SWOT (Strengths, Weaknesses, Opportunities, and Threat) was used for the evaluation of the specification of fire water availability in the new climatic conditions using the example of the Czech Republic. The SWOT analysis originated in the second half of the 20th century in the United States. It is a useful and very versatile analytical technique for understanding and interpreting strengths and weaknesses and for identifying opportunities and threats. It is most often used in business as a strategic tool that can be used for business development (Fine, 2009; Newton et al., 2013).

The SWOT analysis consists of the evaluation and analysis of the current state of the assessed subject/topic, its internal environment and the current situation around the assessed subject, the external environment. The essence is to identify strengths and weaknesses in the internal environment, that is, what the subject is good at and where it lags behind, and the opportunities and threats that are in the external environment which the subject cannot influence (Sarsby, 2016). First, the strengths that are perceived as internal strengths are analysed. Above-standard skills, knowledge, potential and resources are determined, which can be used for the benefit of society in the future. Weaknesses are the opposite of strengths. This area primarily includes the internal weaknesses of the organization/issues addressed, in which better results could be achieved. Potential possibilities for improvement have been chosen as opportunities, provided they are used properly. External facts have been identified that could bring success in the future. Threats are external conditions that can make it difficult or threaten the achievement of goals. Threats have been identified as negative aspects, which must be taken into account and systematically prevented.

In order calculate the weight factor, it was necessary to determine the evaluation item. The evaluation was done on the basis of multi-criteria decision-making. Decision-making means the selection or classification of the value of one variant from the specified criteria. There is a conflict of interest in the decision-making, wherein it is difficult to determine priority values in socio-economic systems. Different groups of people prefer different decision-making consequences and assessments, and different criteria are offered to assess the degree of the optimal decision. In order to evaluate the individual properties of the SWOT analysis, criteria were determined for the possibility of usability of surface and ground fire water, its availability and potential construction modifications.

3 Results

There are a number of methods for identifying risks in safety engineering. When using existing methods in safety analyses or in the alternative design of a new method, basic characteristics must be observed. The following principles are a characteristic feature of each method used:

(a) it should be scientifically defensible and suitable for the system under consideration,
(b) it should provide results in a form that improves understanding of the nature of the risk and the ways in which it can be regulated,
(c) it must be able to be used by different professionals in such a way that it can be traced, repeatable and verifiable for risk verification.

However, for its application, for example, with regard to the assessment of usable fire water reserves in the relevant region, it must segmentally focus on the following defined safety issue areas. As part of the primary structure of the method of the issue in question, it is necessary to implement the following steps:

(a) basic deliberation of which results are to be achieved,
(b) determination of the operating area of firefighting,
(c) finding all critical factors that may reduce or eliminate use,
(d) analysis of the operational-safety environment for the collection of fire water from the aquatic ecosystem or multipurpose source of fire water,
(e) implementation of control mechanisms for long-term sustainability of the chosen method in practice.

Due to the relative complexity of the issue leading to the achievement of the set goal, it is appropriate, before its use and as part of the task in question, to arrange the sequence of ideas in a so-called mind map.

3.1 Defining a threat in a risk analysis mind map

The mind map must be understood as a permanently living document that has no given format. Its aim is to define the range of issues that must be addressed in the individual steps and to which the researcher must obtain a sufficient answer. In order to deal with emergencies, they must obtain answers to the following questions:

(a) what issues have arisen thus far in terms of natural sources of fire water?
(b) What issues have arisen thus far in terms of natural sources of fire water, but when using multipurpose fire water sources.

(c) What are the hypotheses for each problem or question in terms of dealing with the issue of fire water supplies in the case of alternative, significant climate change?
(d) What tools are necessary in order to answer individual questions and their summary areas?
(e) Which input data must be obtained to deal with the problem from the statistical data of the state administration in climate development?
(f) What entry barriers can exist and thereby complicate the solution?

It is always appropriate to follow up on the aforementioned and other questions, depending on the scope of the task in question, as part of the methodology, by defining the input requirements for their fulfilment. The input information requirements may, for example, have the structure in the mind map shown in Table 1.

The sample image of the alternative mind map indicates that it will be necessary to use, for example, the risk analysis procedure below to resolve a specific analytical task. The given procedure with individual steps, see Table 1, deals with the analysed and subsequently specified strengths and weaknesses of the relevant fire water system.

3.2 Applicable risk analysis methods for fire safety in an area

In order achieve the goal, for the relevant step, it is appropriate to use the SWOT analysis from amongst the entire range of applicable methods. This method makes it possible to formulate areas of strengths, weaknesses, opportunities and possibilities for the relevant topic. In particular, the SWOT analysis makes it possible to define the necessary evaluation characteristics for fire water sources (Table 2); due to the length of the text, the individual operational steps are specified in a reduced form. Formulation and subsequent evaluation of individual characteristics of the SWOT analysis were performed by an expert group composed of representatives of relevant bodies and organizations: Faculty of Safety Engineering TU Ostrava, Fire and Rescue Service of the Czech Republic, Faculty of Health and Social Sciences of the University of South Bohemia, Povodí Vltavy, Povodí Moravy, Regional Office—Department of the Environment, Moravian-Silesian Region, Lesy České republiky.

The indicated strengths and weaknesses, opportunities and threats in the analysis must be supplemented in the analyses by defining the absolute value determined by the numerical series, the weight factor and the strength of the criterion of the relevant factor. Based on the outputs from this SWOT analysis, it is necessary to make multicriteria decisions. Subsequently, the value of the weight criterion is calculated, which is based on the Fuller triangle, and the determination of the priority of individual elements of the SWOT analysis. The subsequent product of the determined values determines the strength of the individual criterion. The calculation of the SWOT analysis is presented in Tables 3 and 4.

The evaluation and specification of fire water availability in new climatic conditions using the SWOT analysis and Fuller's triangle are summarized in Table 4. It is clear from the given values that the overall positive evaluation is slightly higher. A positive assessment of strengths and opportunities prevails over weaknesses and threats. The conditions and individual characteristics specified in the case study focused on the Czech Republic need to be further developed with a particular focus on the expert skills of the relevant responsible managers. It is also necessary to strengthen the technical preparedness of the affected entities and fire protection units. In parallel with aiding of

Table 1 Alternative structure of the mind map for the use of fire water resources

Questions	
What problems have occurred thus far with natural water sources?	Can the situation be resolved in the event of an emergency and in what ways?
What problems have occurred thus far with fire water?	Are fire water resources only disturbed to a limited extent and to the extent of natural conditions?
Does the new situation threaten the fire security of the area?	Are there always advantages and positives when using multi-purpose fire water sources?
Sources of fire water and their reliability in new climatic conditions	
Will only the local part of the developed areas of the Czech Republic always disrupt fire water sources?	Should the construction of monitoring be divided into stages?
What are the hypotheses and proposals for the optimal solution for implementation	In what state are the multipurpose sources of fire waters of cities, municipalities, and industrial zones?
- in a standard environment?	How does the national coordinated system of aquatic ecosystems function?
- for the occurrence of a large-scale emergency?	
Objective	
Increasing the volume capacities of water supplies for fire purposes.	

Table 2 SWOT analysis of the Internal and External Environments

Strengths	Weaknesses
Internal environment	
Applicability of surface water for firefighting in most cases, in particular in undeveloped areas	Often greater collection point distances for natural water sources from alternative uses for firefighting
For groundwater, depending on the type of its occurrence in shallow aquifers, in particular at depths up to 6.5 m	For groundwater, an alternative lower volume quantity and the need to know the outputs of its capacity from the monitoring of the relevant collection point
Easy availability and use of fire water for most mobile firefighting equipment	The threat of a significant reduction in the number of natural sources of fire water in undeveloped land as climate change continues
Protection of natural water resources by the Water Act	Ditto, but collection point capacities in the upper flows of recipients
Permanent renewable nature of surface and underground fire water sources. For multipurpose sources, the continuous expansion of water systems for public use, including the use of water for fire needs	Insufficient knowledge of the actual hydraulic capacity of a large part of the recipients and their development trends during climate change
Opportunities	**Threats**
External environment	
Accelerating the expansion of monitoring the hydraulic usability of running water for fire needs	Reduction of the number of usable fire water collection points from underground sources
Preparation of a new operational plan for the development of fire safety in undeveloped areas of the Czech Republic	Elimination of a large part of the upper streams of small recipients from usability for fire needs
Greater involvement of water supply systems in terms of fire protection of undeveloped areas,	Delays in the construction of small natural water accumulations on small watercourses
Reassessment of the actual hydraulic efficiency of a large part of fire water collection points from public water supply systems	Underestimation of crisis planning and its importance for fire protection of regions affected by climate change
Revision of current crisis plans and crisis preparedness plans in accordance with the negative development of water supplies of natural origin	Ditto, but the importance of crisis preparedness plans of dispersed entities and their buildings in undeveloped areas of cities and municipalities

the area of support for forces and resources, it is necessary to maintain and develop the established system of planning and provision of fire water, also in the context of legal documents.

In addition to SWOT analysis, in safety engineering, when assessing the risks of aquatic ecosystems (Bross, 2017) and water systems (Intrieri et al., 2020; Yang et al., 2020) performing the tasks of multipurpose fire water sources, the following other methods can be preferentially used:

(a) Fault Modes and Effect Analysis (FMEA) method, expanded by the Failure Modes Effects and Criticality Analysis (FMECA) method, that is, an analysis of the types, consequences and criticality of states,
(b) checklist method; in this case, this is an additional method pursuant to ČSN IEC 300-3-9; this technique identifies the hazards that are typical for a given type of water source, its significance for the fire safety area and its vulnerability to natural or anthropogenic events.

Table 3 Weighted scores from the SWOT analysis calculation

	Strengths	Weight factor	Assessment	Strength of criteria
Internal environment	1. high degree of organization and technical equipment of fire protection units throughout the Czech Republic and the combined possibility and ability to take fire water from natural and multipurpose sources	0.27	5	1.07
	2. elaboration of individual type plans for specific crisis situations associated with the occurrence of large-scale fires in developed and undeveloped regions of the Czech Republic	0.33	4	1.67
	3. permanent increase in technical and organizational securing of selected buildings and areas with a higher probability of fires	0.13	3	0.40
	4. legislative support for the development of fire safety in a territory in connection with the development of technology and monitoring systems in fire protection	0.07	3	0.13
	5. teaching fire safety specialists at secondary schools and mainly universities in the Czech Republic	0.20	5	0.60
	Subtotal			3.87
	Weaknesses			
	6. ambiguity of competencies primarily between water authorities of regions, municipalities and legal entities responsible for the maintenance of natural sources of fire water	0.13	−2	−0.27
	7. low management activity in the process of maintaining the sustainability and renewable nature of natural water resources, in particular in areas with passive development of water resources	0.27	−4	−0.80
	8. insufficiently evaluated possibilities of using water supply systems (so far) to ensure fire water collection for the protection of undeveloped areas and transport infrastructure in difficult-to-access areas of the Czech Republic	0.07	−4	−0.07
	9. current relatively low requirements in crisis planning for hydraulic and capacity coverage of Fire Brigade requirements from multipurpose sources of cities and municipalities in the Czech Republic	0.33	−2	−1.33
	10. insufficient transfer of information and elaboration of planning documentation on the level of municipalities in relation to the conceptual securing of local public and technical infrastructure of the developed area	0.20	−3	−0.60
	Subtotal (total proportion)			−3.07

Table 3 (continued)

	Strengths	Weight factor	Assessment	Strength of criteria
External environment	*Opportunities*			
	11. significantly higher use of scientific research of knowledge and theoretical-practical outputs from universities, in particular from VSB TUO-Ostrava, FBI, in terms of using various types of extinguishing agents to extinguish fires and reduce secondary and tertiary damage to the property of the extinguished building	0.27	4	1.07
	12. new defining and determination of usable means for dealing with extraordinary events in crisis plans with the use of inventories in the buildings of the State Material Reserves Administration	0.07	2	0.07
	13. carry out exercises focusing on alternative possible scenarios of fire hazards in the new climatic conditions and the exclusion of some natural water sources from the fire water supply plan in the coming decades of the 21st century	0.20	3	0.60
	14. timely processing and implementation of preventive fire protection measures and alternative solutions to the negative impact of the lack (at least of a local nature) of fire water for extinguishing fires	0.33	5	1.67
	15. increase the international exchange of experience in the field of fire protection of a territory with the possibility of cross-border and international cooperation	0.13	3	0.40
	Subtotal (total proportion)			3.80
	Threats			
	16. generalization of approaches as part of crisis management in crisis planning of territorial protection and underestimation of climate change threats	0.13	– 3	– 0.40
	17. crisis management inexperience and insufficient education in the field of crisis management of safety engineering processes and new possibilities of using extinguishing agents	0.27	– 4	– 1.07
	18. difficult coordination of a large number of different entities involved in management of crisis situations	0.07	– 1	– 0.07
	19. exclusion of a multipurpose source of fire water of a city or municipality, from (local water supply system), dependent on pumping or treatment of drinking water, in the event of total failure of electricity supply for the water supply system, local or international significance	0.33	– 5	– 1.67
	20. sidelining the issue of crisis management associated with fire water at the expense of other disasters in crisis planning of state administration and crisis preparedness plans of legal entities and individuals doing business	0.20	– 2	– 0.40
	Subtotal (total proportion)			– 3.60

Table 4 Summary of the Weighted scores from the SWOT analysis

Internal environment	Strengths + Weaknesses	0.80
External environment	Opportunities + Threats	0.20
Total (difference)		+ 0.60
Positive environment	Strengths + Opportunities	7.67
Negative environment	Weaknesses + Threats	− 6.67
Total (difference)		+ 1.00

4 Discussion

Depending on the alternative increasing threat of severity of at least regional surface and groundwater scarcity in usability in fire protection of an area, it is appropriate to perform a safety analysis of all strategic or irreplaceable fire water sources in the manner indicated in this chapter of the article. The performed risk analysis can answer for the task researcher well in advance the question of whether there is a risk, what its nature is, what its strengths and weaknesses are, and it also indicates by what means the threat can be minimized. In many cases, with the ongoing climate change, it will most likely be necessary to replace natural sources of fire water with multipurpose sources, and in extreme cases with artificial sources. Which of the possible and realistic variants will be used always depends not only on the technical and economic parameters of the relevant fire water collection point, but in particular on the long-term sustainability in active operation.

It arises from the text of the article and its broader concept that, despite the current satisfactory situation in fire protection in the Czech Republic regarding fire water, the risks of its shortage are increasing when the climate changes significantly. The lack of fire water will not be nationwide, but most likely only regional. However, even a regional lack of fire water is a serious threat to the fire safety of a territory. For the most part, it will be possible to reduce the given threat by increasing the use of multipurpose fire water sources, primarily from water supply systems of water systems and local water supply systems of towns and municipalities. The overall reduction of threats of fire water shortage in the Czech Republic must be subjected, in a timely and preventive manner, to a scientific examination of individual natural dependencies and anthropogenic developments in this state administration sector. The Czech Republic has sufficient potential to address the situation of impending climate change.

Expert evaluation and specification of fire water availability in new climatic conditions using the example of the Czech Republic were performed using the SWOT analysis, and evaluation was done using Fuller's triangle. Based on the overall evaluation, a slight predominance of positive characteristics is evident — strengths and opportunities. The used methods can be evaluated as suitable for dealing with the selected area. The used methodological procedure involves the danger of influencing the evaluation based on individual emotional experience. This risk was minimized thanks to the evaluation of an expert group, the members of which argued with each other and discussed the partial performed evaluations.

Another objective of the article is the characteristic of the possible lack of fire water and a proposal of means by which can be achieved the maximum effect with minimum investment costs, and to ensure long-terms sustainability of natural and multipurpose fire water sources. Basic information about the procedure and the chronology of steps almost always arises from the SWOT analysis, indicated herein in the article and in Table 2, which deals with the internal and external aspects of water ecosystems and water supply systems. The details including the suitability of their use are indicated in the article in Tables 3 and 4, which can be used for final multi-criteria decision-making.

Current scientific knowledge suggests to a sufficient extent that a satisfactory result can only be achieved through a deep analysis of both systems, identification of their strengths and weaknesses, and to propose in the solution appropriate implementation procedures in practice. The Czech Republic and its scientific base have sufficient knowledge and resources to safely achieve both goals. The solution is to strengthen the combination of natural fire water resources and increase the proportion of multi-purpose resources through the methods defined in the contributions and the project task. State administration, regional self-governments and the professional public dealing with fire safety in the Czech Republic must respond on time to the threat of water shortage for fire purposes (Bozek et al., 2014; Kováčová et al., 2014; Pokorný et al., 2015).

The growing trend of inequality between the needs and capacities of aquatic ecosystems must be considered a very certain factor. In terms of securing an area with fire water, only accumulated surface water can be considered a sufficient source for the 21st century. In some specific cases, even running surface water can be used as a source. Regarding groundwater, the possibility of using shallow groundwater resources is decreasing and will continue to decrease. This situation is in conflict with the current development of fire equipment and the method of collecting fire water to a maximum depth of 6.5 m. Therefore, in the case of scattered developments, it will be necessary to decide whether to increase the pressure on the use of a multipurpose source with sufficient volume capacity or to conduct a hydrogeological survey in localities at risk of fire water shortage. In real practice, it can be stated that in the vast majority of cases it will be necessary to increase water collection from water systems for fire needs, and in many cases also the construction of new large-capacity water collection points from water systems.

5 Conclusion

The developing climatic conditions and the protection of fire water resources are two interrelated current aspects that society will have to solve. In addition to its basic function as a source of life, water is an integral part of the fire protection and safety system. Experience and accurate records of climate measurements in modern history indicate developing and changing conditions to which society must respond. A prerequisite for the resilience of society in response to possible emergent events and disasters is the elaboration of a situation analysis and risk analysis.

The outputs of analytical methods always aim to achieve optimal information in order to propose subsequent steps to eliminate risks in real time and economic feasibility. Safety can never be ensured perfectly and completely, and this claim can also be applied to crisis situations related to fire water sources. Moving towards complete safety or the idea that serious threats can be completely averted or eliminated is erroneous and dangerous. The concept of societal vulnerability, which maps, categorizes and measures vulnerabilities, serves to describe the level of safety. In addition to strengthening safety capacities, it is necessary to create a safe space and an overall safe environment, e.g. in the form of river basin protection, landscape protection, and spatial planning.

The evaluation of aquatic ecosystems, including firewater resources, is scientifically and technically extremely complex. The complexity of the assessment arises from the simultaneous effects of natural and anthropogenic influences over time on surface and groundwater resources of different types of watersheds and their vulnerability. Large-scale changes can be identified, particularly at the end of the last century and the beginning of the current 21st century. The situation varies considerably between the different countries of the European Union. For example, the Czech Republic is one of the most hydrologically vulnerable regions of the European Union. There are a number of ways to reduce the risk of exposure to and consequences of emergencies. One of the main approaches is to manage the protection of aquatic ecosystems on a supra-regional basis over the long term. With rigorous adherence to scientific knowledge and further dissemination on aquatic ecosystems, including the use of optimal risk analysis methods, acceptable results can be achieved in most cases. One of the primary prerequisites is the development of an idea map, in which the final goal must be sufficiently clearly defined, while at the same time setting out a number of sub-measures and tasks that are conditional on the achievement of the main goal.

Always and without exception, it is necessary to define the strengths and weaknesses of the analysed aquatic ecosystem in the risk analysis and to define the results of the analysis, for example, by the SWOT method, in the relevant section of the risk analysis. All the basic steps to achieve an optimal result are outlined in this paper, not only in terms of expert knowledge, but also in terms of the public debate on the subject. Expert dialogue will certainly become increasingly important as the global climate evolves at least until the end of the 21st century.

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Declarations

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