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Study of supply of drinking water in dry seasons in the Czech Republic

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Abstract. Models of climate change assume a long-term growth in temperature. This poses a risk for the supply of drinking water to the population. This paper evaluates the possibilities of optimal use of surface and underground sources. It proposes the interconnection of surface resources and optimization of their use. In order to improve the yield of underground water sources, it recommends the use of artificial infiltration.

1. Introduction

Climatic changes associated with global warming have been and will be causing extensive deficiencies in the water cycle. Estimated climatic models predict a world-wide growth in temperatures and thus occurrence of droughts. No matter how the prognoses will turn out, it is vital to prepare measures in order to ensure water supplies in the dry periods.

Changes in the climate influence the quantity and quality of groundwater and surface water, and insufficient precipitation causes lower surface run-off and thus affects the quantity of groundwater. This leads to lower flows in watercourses, drops in the groundwater levels and lower yields in springs. Altogether, the phenomena eventuate hydrological droughts. In addition, higher temperatures cause higher evaporisation.

Drinking water supply belongs among basic infrastructure services as for population’s needs. Climatic changes are a threat for which measures must be prepared. In the Czech Republic the water resource situation is very difficult as all water originates in precipitation. Problems associated with drought have manifested for several years and are assumed to aggravate. The strategy for dry periods should lie in such measures so that the water supply via public water mains is not interrupted. The measures may be classified into two areas. Measures on the part of resources mean that their protection must be increased, and additional sources of water must be searched for. On the part of water take-off, it is necessary to prepare measures leading to lower water take-off in order to ensure continuous water supplies in case of a water deficit.

The experience from the dry year 2015 shows that drought varies in its intensity in the different regions. In this we perceive a possible solution in the form of cooperation of the different surface water sources. Interconnecting the sources, the dependable yield of the sources may be increased. The interconnection is also advisable in larger scales. It means that whole water supply systems should be interconnected, which shall ensure water supplies also in regions with the current drought. The solution in groundwater resources may be artificial infiltration to store water for the dry periods.

2. Prognoses of climatic changes and their impact on water balance

The Czech Republic falls in the mild climate zone of the Northern Hemisphere. The climate is characterised by dominant westerly wind and intense cyclonic activity. The majority of the country receives annual 500 – 700 mm of precipitation; wetter regions from 700 – 1000 mm of precipitation a year. In the mountains, the maximum precipitation may reach 1700 mm. On the contrary, the driest sites have an annual precipitation of 410 mm only [1].

According to the estimates of the Czech Hydrometeorological Institute [2] the Czech Republic may expect an increase in the mean annual temperature of air of 1.4 – 1.8 ^{o}C between 2021 and 2050. Between 2071 – 2100 the temperature is assumed to grow by 3.3 – 3.7 ^{o}C. The data have been related to the reference period of 1961 – 1990. A future drop in precipitation is expected in summer. Extreme phenomena will occur on a more frequent basis. The expected threats are torrential rain and drought. The weather models estimate a future decrease in winter precipitation of as much as 20 %. In spring the precipitation is supposed to increase by 2 – 16 % depending on the different regions. The summer and autumn will experience a significant spatial variability in precipitation. Overall, there will be a drop of as much as 30 %; in places there may be an increase of as much as 10 %. The precipitation models show considerable fluctuations in precipitation in the different regions. As for reliability, the prognoses for the Czech Republic correspond to the prognoses processed by the German meteorological services [3]. For the period 2021 – 2050 they assume an increase in temperature of 0.5 – 1.5 ^{o}C and by 2100 a rise in temperature of 1.5 – 3.5 ^{o}C. Warming should be more apparent in winter and more frequent extreme phenomena are assumed, such as intense rain, sea storms or long droughts.

The year 2015 is an example of a dry period. Within the territory of the Czech Republic it has been evaluated the hottest year for the past 134 years, i.e. the whole period under measurement records. There were 36 tropical days and the majority of the meteorological stations recorded new maximum temperature records. Lower precipitation was observed from the end of February and by the end of October the precipitation was lower by 165 mm, i.e. a drop of 30 %. Figure 1 shows the accumulated course of rainfall compared to long-term values [4].

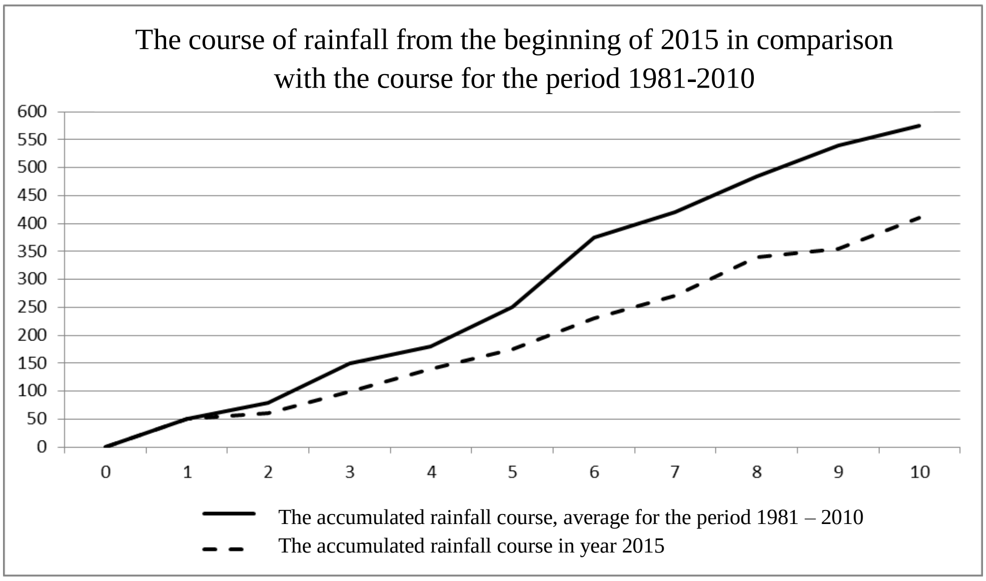

Figure 1. The course of rainfall from the beginning of 2015 in comparison with the course for the period 1981-2010.

The flow rates in rivers ranged from 10 to 50% of long-term mean annual discharge. The drought also manifested in the reserves of groundwater. 40% of all bores had seriously subnormal reserves. A more favourable situation was in water supply reservoirs on watercourses. The live capacities of the reservoirs were filled at 40 – 60%. This drought showed in the continuity of water supplies only partially, mainly due to large capacities of sources over the water demand.

3. An overview of drinking water supply

In the Czech Republic over 94 % of population take water from the public water mains. Annually, 624 mil. m^3 of drinking water are produced. One half of the produced volume originates in surface sources and one half comes from underground sources. The surface sources are mainly water management reservoirs on watercourses. The underground sources are both deep and shallow. The water discharge intensity for households ranges around 90 l per person and day. Good news is that nowadays the water source capacities have been used out of 60 %. The consumption of drinking water has dropped by half when compared to the period before 1990. After 1990 the Czech Republic has launched market economy. In terms of drinking water supplies, this meant that the previously state-subsidised water costs increased to cost price. Water take-off has decreased along with a rise in the price of water. For example, in 1990 the water discharge intensity for citizens was 170 l per person and day [5]. The experience of the year 2015 shows that the drought that lasted for the almost whole year did not significantly affect the continuity in drinking water supplies in water mains supplied from surface sources. However, there were problems with smaller groundwater sources. The experience of last century dry periods shows that there were 2-3-year droughts. Two-year droughts occurred approximately once in 10 years; three-year droughts occurred every 20 years. It is important to focus on longer periods when preparing measures for the dry periods [6].

4. Measures for water supplies from surface sources in longer dry periods

To assess the options for drinking water supplies in long dry periods, we used data and findings from the year 2015. To model how long certain sources of surface water may ensure continuous water supplies, we selected a locality in north-western Bohemia. The locality is situated in the rain shadow of the Krušné hory Mountains, where also the driest region of the Czech Republic, Žatec Basin, is situated. The mean annual precipitation ranges from 450 to 550 mm. As much as 84 % of population are supplied from the public water mains. The sources are water management reservoirs Přísečnice, Fláje and Žlutice. Water is treated for drinking water in water purification plants.

Přísečnice Reservoir has an overall volume of 54.7 mil.m^3, the live storage capacity is 46.7 mil.m^3, and the maximum allowable water system take-off is 960 l/s. The standard water system take-off is 490 l/s, which is 51 % of the maximum allowable take-off. The minimum long-term run-off of 50 l/s must always be ensured. At the minimum inflow into the reservoir in dry periods, the water supplies shall suffice for two years.

Fláje Reservoir has the overall volume of 23 mil.m^3, the live storage capacity is 19.5 mil.m^3, and the maximum allowable water system take-off is 510 l/s. The standard water system take-off is almost 500 l/s. The minimum long-term run-off was set as 75 l/s. In 2015 the storage capacity was used up from 48 % only. At the minimum inflow into the reservoir in dry periods, the water supplies would suffice for 286 days.

Žlutice Reservoir has the overall volume of only 15.6 mil.m^3, the live storage capacity is 10.4 mil.m^3, and the maximum allowable water system take-off is 190 l/s. In 2015 the standard take-off is 86 l/s. The minimum long-term run-off into the catchment area is 220 l/s, which is rather high with regard to the volume of the reservoir. This is to ensure water supplies into the catchment area below the reservoir. At the minimum inflow into the reservoir and maintaining the conditions, the water supplies would suffice for 235 days.

The situation in the reservoirs of Fláje and Žlutice is not very favourable as for ensuring continuous water supplies in dry periods. If the drought of 2015 had lasted longer, water supplies would have been ensured only for 8 months. The estimated droughts in the future may last from two to three years. This may be solved via interconnecting the water management systems of Přísečnice with those of Fláje and Žlutice. In such a case, the overall water reserves would last for 15 months. This way, it is a suitable measure for the future as new construction and capital repairs are needed. Prepared are also emergency measures, such as lower run-off from the reservoir into the catchment in order to prolong continuous water supplies to 2 years.

The model example shows that an interconnection of water management systems may ensure continuous drinking water supplies in times of drought. Considering longer dry periods, it is vital to prepare regulation measures to reduce drinking water take-off by customers. This is to ensure a continuity in drinking water supplies as any discontinuity leads to larger water losses.

In the Czech Republic, there are a number of extensive water management systems supplied mainly from surface reservoirs. This is another area, where solutions must be searched for, as the drought prognoses for the next 30 – 50 years are not favourable. However, this requires a solution in the form of investments that will be very costly. The implementation of such measures shall last longer than 10 years. To be specific, we may speak of interconnecting the Ostrava regional public water mains, where there is a permanent surplus in surface water sources, with regions in central Moravia. Central Moravia mostly has underground water sources and when compared with Northern Moravia (with its Ostrava regional public water mains) central Moravia has minimum rainfall. Another solution is an interconnection of a number of reservoirs, such as Přísečnice, Fláje and Žlutice and the North-Bohemian Lower Krušné hory public water mains, which is supplied from heavy rainfall from the Krušné hory Mountains. As an example, we may use the public water mains in Eastern Bohemia. It is a system predominantly supplied from underground sources. The system has been expanded into the Pardubice Region and Pěčín Reservoir was built. This shall ensure water supplies for the estimated period of 2030 – 2050. There are large reserves in the Vír regional public water mains to strengthen supplies for the wider Brno agglomeration. Another public water mains system is Southern Bohemia with its reserves. This system may be interconnected north-westwards with Příbram Region.

Apart from interconnecting the public water mains systems, the reliability of the systems is also important in case of emergency. If there is a failure in the local system, we cannot speak of cardinal problems. More serious problems may occur in case of failures of long-distance water management supply lines. Currently, the Czech Republic has more than 2700 km of long-distance supply lines (cross-section 400 – 1600 mm). One third of these is older than 50 years. Besides the prognoses of climatic changes, it is important to plan the revitalisation and modernisation of the existing water management systems for the future.

5. An increase in groundwater reserves for dry periods

In the Czech Republic, a half of drinking water reserves comes from the underground sources. However, in times of drought these groundwater sources are also under threat. This predominantly concerns more shallow underground sources, in which their yields fall quickly in dry periods. On the contrary, in deep underground water sources the yield falls less quickly, but filling in the sources make last many years. One option to improve the situation is artificial infiltration, which used to be applied more widely in the past. At present, artificial infiltration is applied in Kárany on the Jizera River.

Artificial infiltration may largely help water sources in dry periods. However, the selection of a suitable locality for artificial infiltration is not easy. Sources of surface water must be available for infiltration, which may be a problem in dry periods. Another important question is the quality of water to be infiltered underground. The choice of a suitable locality is thus crucial. Such suitable areas may be plots along the Bečva River. In the past, this method used to be applied also in Rožnov on the Rožnovská Bečva River and the Bečva River in Hranice and Lipník. Another suitable locality may be plots along the Odra River in the Odry Valley. This is supposed to be verified by research and technical solutions must be designed.

6. Conclusion

The development of the last decade has shown that the expected climatic changes are already taking place, namely there are longer dry periods and higher temperatures. The existing experience shows that in the Czech Republic this is a problem that may be solved. It is possible to interconnect the public water mains systems supplied from surface sources in order to optimise the different systems' capacities. Droughts do not always affect the country evenly and water supplies may be continuous also in drier regions. Artificial infiltration may be used in underground sources. However, it is vital to assess the possibilities of the different localities with respect to the water quantity and quality suitable for infiltration underground.

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