Evaluation of Hydro-Meteorological Conditions at the Water Reservoir for Supply of Drinking Water in the Period Since its Commissioning

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Abstract

Safe drinking water and its abundance include into among the basic attributes of a healthy environment and the basic human rights. As climate change progresses, ensuring a supply of drinking water to the population will pose increasing challenges. In this context, apart from exploiting groundwater sources, water reservoirs will assume a pivotal role in addressing this issue. On the territory of the Slovakia, there are currently 8 water reservoirs, which are used to collect water for the production of drinking water. One of them is the Turček reservoir, which was completed in May 1996 and has been in full operation since 1997. In this contribution, the hydro-meteorological data from the Turček water reservoir location, which were provided by the operator of this reservoir, are evaluated. These data contain information on daily values of basic characteristics. The period 1997-2021 was analyzed, especially the development and trends of precipitation, air temperature, occurrence of a given type of weather during this period and ice cover thickness and duration. The analysis of hydro-meteorological data showed that the average annual air temperature is rising slightly, for the period 1997-2021 it rose by 0,03 °C. The ice cover thickness (both maximum and average value) shows a decreasing trend and decreased by 7,3 cm during the observed period. The same trend is shown by the duration of the ice cover on the reservoir surface. The frequency of precipitation events has been decreasing for a long time, the annual total depth of precipitation also has a decreasing trend. Recently, this reservoir also had a problem with the occurrence of cryophilic cyanobacteria, the occurrence of which is not desirable in such types of water bodies. The performed analysis of the development of hydro-meteorological conditions is an important basis for the evaluation and understanding of processes related to water quality in this reservoir.

Keywords: *Turček water reservoir, precipitation, air temperature, ice cover, trends*

1. Introduction

Slovakia is characterized by abundant water resources, encompassing both surface and groundwater reserves, which collectively meet the current and prospective demands of the nation. However, the spatial distribution of these resources is uneven across the Slovak territory, primarily influenced by geomorphologic, geological, hydrogeological, and climatic conditions [1, 2].

Water resources, despite their abundance, are finite and currently face significant challenges due to over-exploitation, persistent anthropogenic pressures, and climate change [3]. These factors can severely affect water quality, an essential resource for human health, ecosystems, and the economy [4]. Degradation in water quality can lead to human exposure to harmful diseases and toxic chemicals [5, 6], reduced ecosystem productivity and biodiversity, and adverse effects on aquaculture, agriculture, and other water-dependent industries [7, 8].

Reservoirs serve as critical sources of drinking water globally and are not immune to the impacts of climate change. These impacts manifest in various ways, such as surface water temperatures increasing [9], stratification patterns altering, ice cover duration reducing [10] and also affecting biological aspects like phytoplankton community shifts and the heightened risk of cyanobacterial blooms. Climate change exacerbates eutrophication processes in water bodies [11]. Unlike lakes, reservoirs exhibit different responses to climate change due to the active management of their storage and outflow [12]. Key operational parameters for reservoir management include the withdrawal rate, withdrawal schedule, and withdrawal depth. The depth of withdrawal is influenced by the thermal stability and material dissipation in a reservoir, thereby affecting the mixing in it [13]. In case of drinking water reservoirs, optimizing withdrawal depth is a critical adaptation strategy to enhance raw water quality for drinking water production [14].

The objective of this study is to analyse the hydro-meteorological data from the youngest water reservoir for drinking water supply located in Slovakia territory - the Turček water reservoir. The period 1997-2021 was analysed, especially the development and trends of precipitation, air temperature, occurrence of a given type of weather during this period and ice cover thickness and duration.

2. Material and Methods

2.1 Description of locality

The Turček water structure or water reservoir began to be built in 1992. Its primary function is the accumulation and supply of raw water, which is the source of drinking water for the Žiar nad Hronom, Handlová and Prievidza districts. Additionally, the reservoir plays a crucial role in flood protection for the upper Turiec stream, maintaining its ecological flow stability throughout the year, and generating electricity through small hydroelectric plants.

The reservoir is situated at the confluence of the Turiec and Ružový potok streams above the Turček village in the central part of Slovakia (the Turčianske Teplice district) (Figure 1). The total catchment area encompasses 29.5 km². The average annual water supply to the treatment plant is 15.8 million cubic meters. The valley width at the site is approximately 120 meters, and the elevation at the dam profile is 719 meters above sea level. The reservoir has a total capacity of 10.6 million cubic meters, with an active storage volume of 9.9 million cubic meters (replenished twice annually) and a constant volume of 0.3 million cubic meters.

The dam's infrastructure includes several structures ensuring the operational functionality of the reservoir. The dam's stability is maintained by a retaining wall with a height of 59 meters and a crest length of 287.6 meters. The dam is sealed with a single-layer asphalt concrete membrane, connected to an injection corridor at the base.

Fig. 1. Situation and photo of the Turček reservoir

2.2 Availability and processing of data

The objective of this study was to evaluate the temporal changes in hydro-meteorological data during the operational period of the reservoir. This necessitated the collection of relevant data. Primary data were provided by the reservoir administrator, the Slovak Water Company (Slovenský vodohospodársky podnik, š.p.), sourced directly from the reservoir site, and supplemented by our own measurements and observations conducted in 2019. All provided data were only in written form, so the first step was to digitize them.

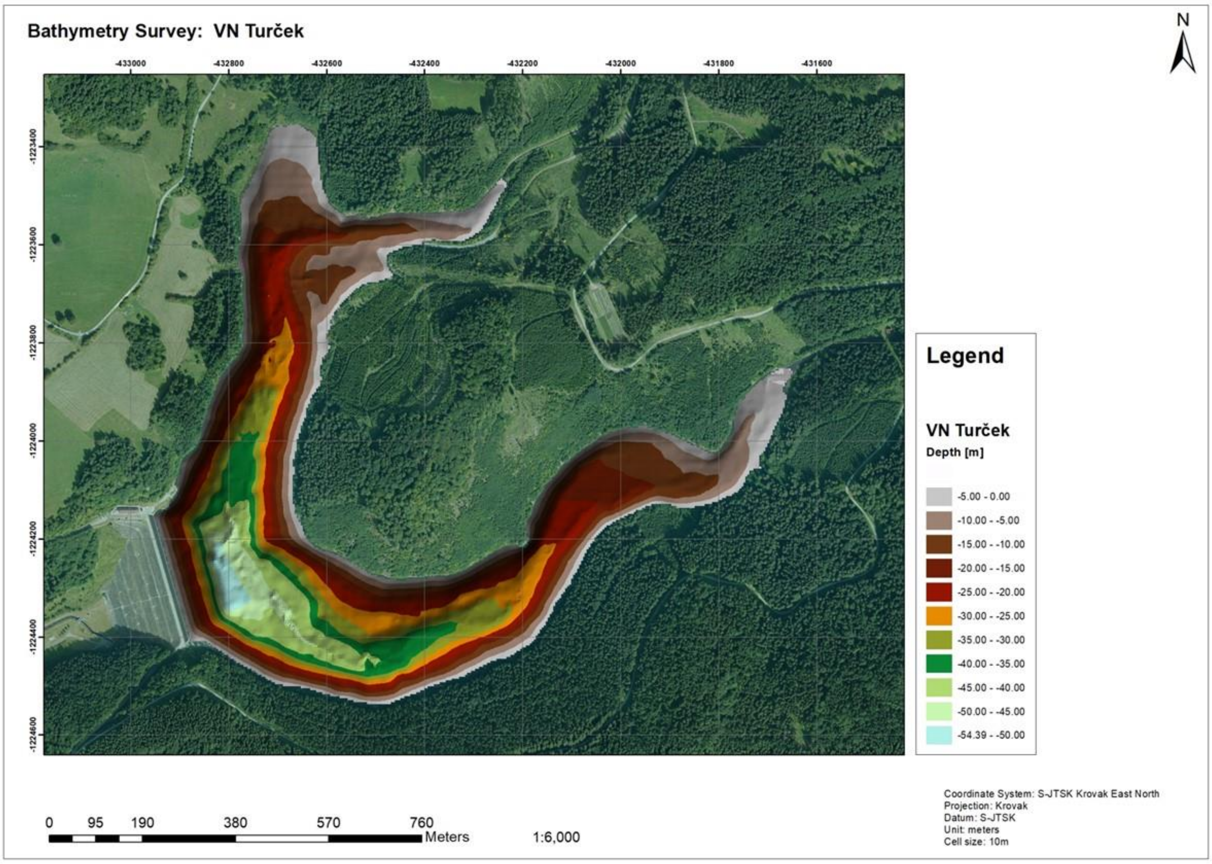

Fig. 2. Bathymetry of the Turček reservoir

There were available hourly recordings of air temperatures, daily measurements of precipitation, information about duration of ice cover with its thickness, and the frequency of various weather types (categorized as 0-cloudless, 1-cloudy, 2-completely cloudy, 3-fog, 4-drizzle, 5-rain, 6-rain with snow, 7-snowfall, 8-showers, 9-storm). Based on these data, there were evaluated the trend of values of monthly air temperatures, annual total precipitation depths, differences in weather during the studied period and in the particular months. Additionally, the current bathymetry of the reservoir was assessed using the AUV EcoMapper device (see Figure 2).

3. Results and discussion

In general, actual climate change is a result of other global changes both natural and anthropogenic. It is mostly felt as a change of ecosystem temperature, increase of precipitation intensities and totals, as well as their irregular distribution in time and space. Flood periods are followed by long periods without precipitations [15, 16, 17]. The Turček reservoir is not so old reservoir, but anyway, the data obtained since its commissioning provide a unique opportunity to evaluate the development of basic hydro-meteorological indicators in the location of this water reservoir. It is very important also from the reason that it is a reservoir for drinking water supply, so acquaintance on aspects affecting its water quality are important.

We began our analysis with a general assessment of weather conditions. In Figure 3 it can be seen the changes of number of various types of weather in partial months at the Turček reservoir locality during the period 1997 – 2021. The most cloudless month is August and the most completely cloudy month is November. Precipitation in form of snow occurs from October to April. The most storm events are in July and foggy days occur throughout the year, but at least in April. For better clarity in connection with the analysis of precipitation totals, the types of weather were divided into three basic types of events, namely sunny (cloudless), cloudy (cloudy, completely cloudy, fog), precipitation events (drizzle, rain, rain with snow, snowfall, showers, storm). Result of this division is shown in Figure 4.

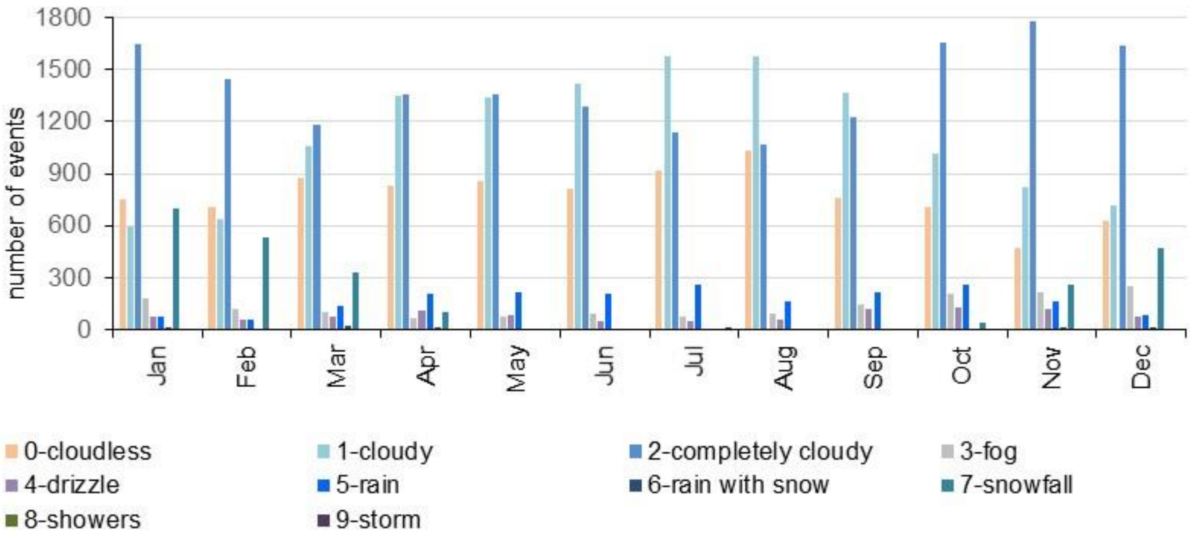

Fig. 3. Number of various types of weather in partial months (the Turček reservoir, 1997 - 2021)

According to this graphic output, the sunniest year was 2002 and 2011, in which more than 500 sunny events was recognised. On the other side, the lowest number of such events was in 2004 and 2014. Regarding number of precipitation events, the most frequent occurrence was in 1998. Anyway, higher frequency of precipitation events does not directly mean the higher amount of precipitation depth.

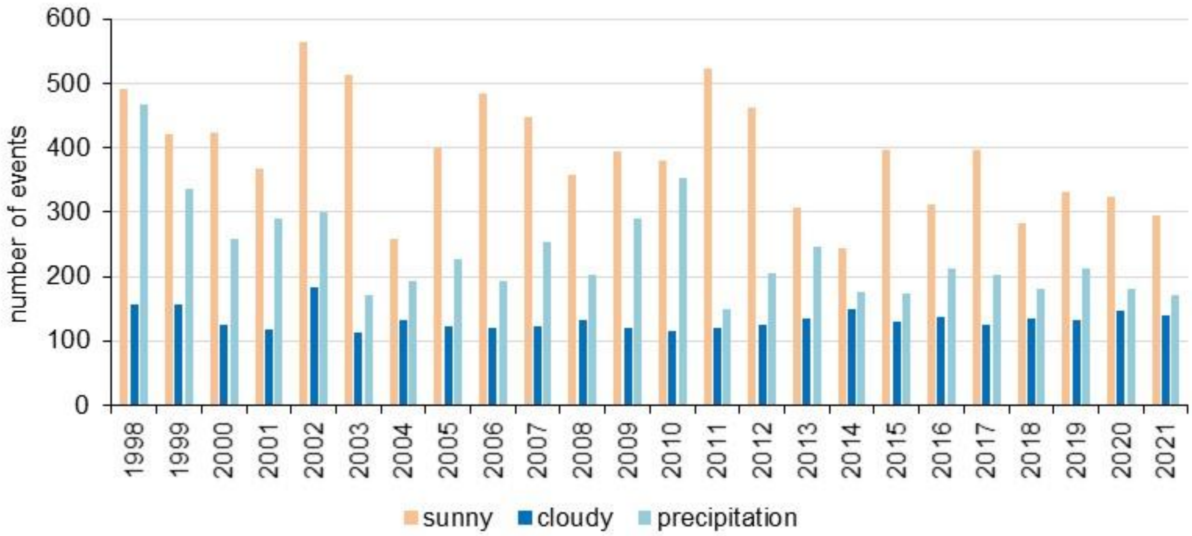

Fig. 4. Number of three basic group of weather types in the monitored period at the Turček reservoir

According Figure 5, the largest precipitation total was in 1998 and 2010, even also in other years the annual precipitation depth was more than 760 mm per year, what is approximately a long term mean annual precipitation total in Slovakia territory. In the analysed period, the totals higher than 800 mm per year were up to 2000, in 2010, 2016 and 2020. In contrast, dry years with precipitation totals lower than 500 mm//year were in 2002, 2015 and 2021 (see Figure 5).

In general, analysis of the annual precipitation totals showed a slight decrease, by approximately 80mm.

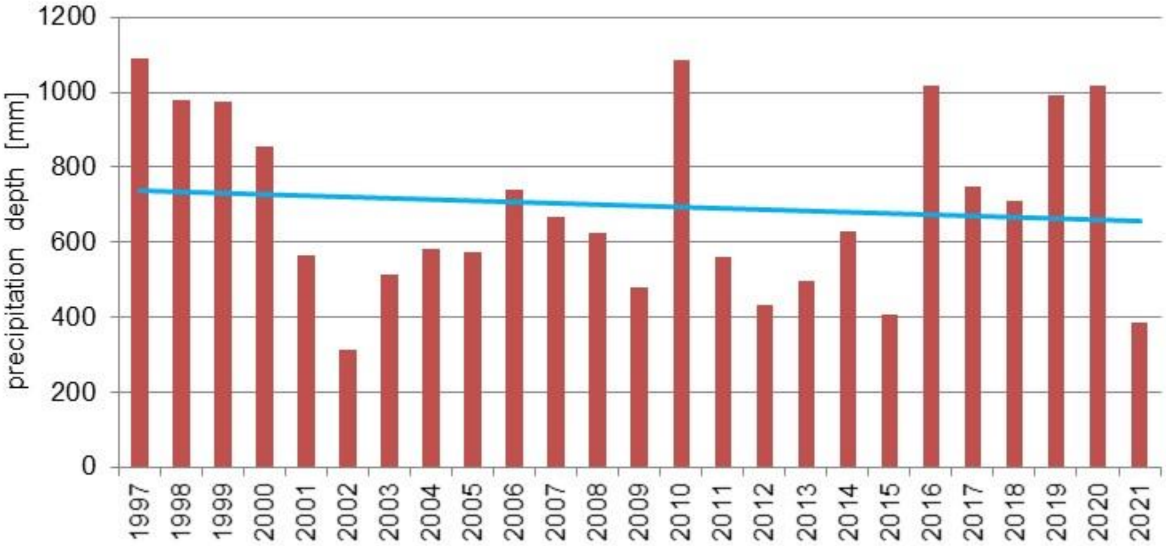

Fig. 5. Time series of annual precipitation depths and their trend (the Turček reservoir, 1997 - 2021)

Air temperature was the next evaluated parameter. Figure 6 shows time series of monthly air temperatures, annual air temperatures and their trend at the Turček reservoir in the period 1996 – 2021. During the monitored period, we observed only a slight increase in the average annual temperature by 0.03 °C.

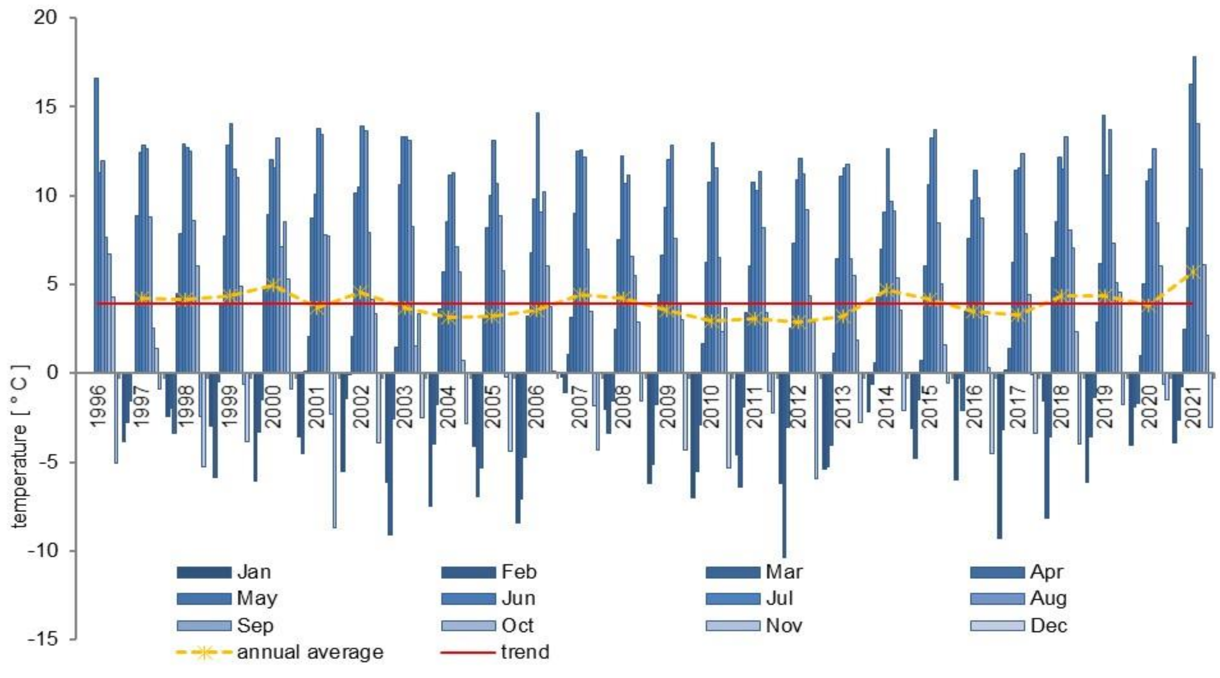

Fig 6. Time series of monthly air temperatures, annual air temperatures and their trend (the Turček reservoir, 1996 - 2021)

In 1996, the reservoir was put into operation, so data on the air temperature was available only from June. Anyway, June 1996 was the warmest one in the monitored period with an average air temperature of 16.6 °C. Regarding minus temperatures in this year, the average air temperature fell in December to -5 °C. The following year 1997 did not reach such maximum values as 1996, the lowest temperature was in January only at 3.9 °C, even April of this year was quite cold, when the average air temperature was around 0 °C. The maximum temperature of this year was 12.7 °C in July. On the other hand, in 1998 the minus temperature appeared already in November. The lowest monthly air temperature were in 2003, 2006, 2012, 2017 and 2018. The most significant temperature amplitudes were recorded in 2003, 2006, 2012 and 2017. Significant warmer years in the period 1997-2021 were 2000, 2002, 2014.

Another evaluated parameter was the occurrence of ice cover, its duration and thickness, which is related to the air temperature and affects the mixing of water in the reservoir. As it can be seen on Figure 7 and Figure 8, both duration and thickness of ice cover at this reservoir has decreasing trend.

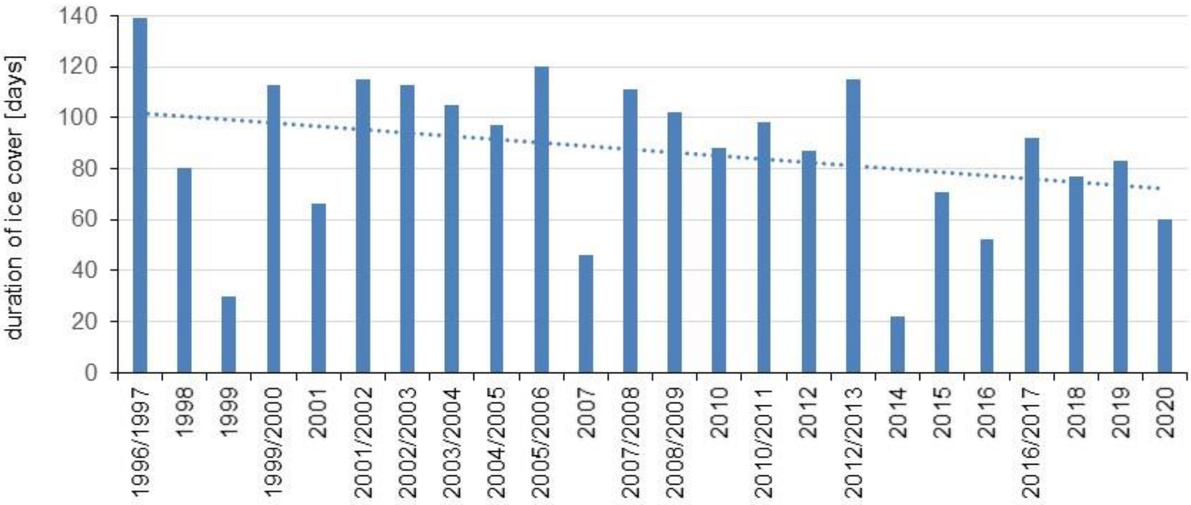

Fig. 7. Duration of ice cover in monitored period (the Turček reservoir, 1997 - 2021)

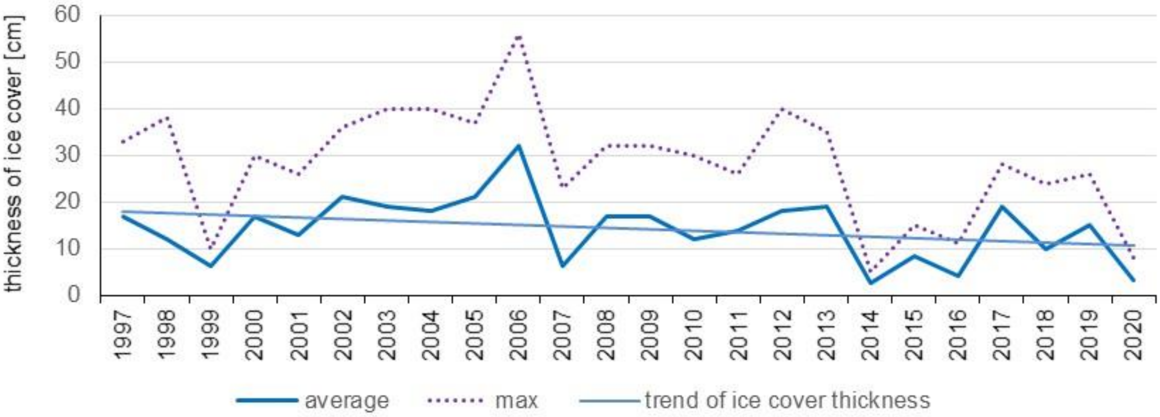

Fig. 8. Thickness of ice cover during monitored period (the Turček reservoir, 1997 - 2021)

The number of days in Figure 7 is not tied to the calendar year, but to the hydrological year (time data like 1996/1997 mean that the ice cover was during this winter season, time data like 1998 mean that the ice cover was only during the winter season in this year). The weakest years for the period with an ice cover include 2007 with 46 days and 2014 with only 22 days. On the other hand, among the strongest years in terms of the length of the ice cover is mainly the hydrological year 1997, when the ice covered the surface of reservoir 139 days and that represents more than a third of the year. Other strong years with the ice cover were the hydrological years 2005/2006 with a cover length of 120 days and 2012/2013 with 115 days. However, the overall trend of the duration of the ice cover shows a decreasing trend, with 46 days less with a frozen surface during the monitored period.

Figure 8 shows the annual mean and maximum ice cover thickness. In 2006, the largest ice cover was recorded - the maximum value of the ice thickness was 56 cm and the average thickness was 31.7 cm. The weakest years concerning the ice thickness are 1999 with a maximum thickness of 10 cm and an average of 6.3 cm, the next one is 2014 with a maximum of 5 cm and an average of 2.6 cm, and in 2016, the ice cover thickness was maximally 11 cm and an average thickness of 4.1 cm. The last years were again weak regarding the ice cover of reservoir. A decrease in the thickness of the ice is by an average of 7.3 cm from 1997 to 2020.

4. Conclusion

The objective of this paper was the analysis of hydro-meteorological data from the Turček water reservoir, which is the youngest water reservoir for drinking water supply located in Slovakia territory. Despite the fact that in Slovakia approximately 80% of the population are supplied with drinking water from groundwater sources, the role of this type of reservoir is irreplaceable, and it is necessary to realize that in some countries such water bodies are the primary source of drinking water for the population.

The period since its commissioning was analysed. Climatic change is relevant for drinking water supply management in multiple ways. Extreme hydro-meteorological events, which are expected to become more frequent and intensive, often lead to temporary deteriorations in raw water quality. For this reason, the occurrence of a given type of weather during the reservoir operation period were evaluated, as well as the development and trends of precipitation, air temperature, and ice cover thickness and duration.

The results of the analyzes of hydro-meteorological data were mainly the following findings:

- the ice cover thickness shows a decreasing trend and decreased by 7.3 cm during the observed period,
- the same trend is shown by the duration of the ice cover on the reservoir,

- the frequency of precipitation events has been decreasing for a long time, the annual precipitation totals also has a decreasing trend,

- the average annual air temperature is rising, for the period 1997-2021 it rose by 0.03 °C.

The performed analysis of the development of hydro-meteorological conditions is an important basis for the evaluation and understanding of processes related to water quality in this reservoir. All findings will be taken into account and used in the next assessment of changes in water quality in this reservoir.

Acknowledgments

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