Seasonal Conditions of Water Temperature in the Hriňová Reservoir

Yvetta Velísková[1*)], Márta Koczka Bara[2)], Marek Sokáč[3)]

[1*)] Institute of Hydrology, Slovak Academy of Sciences, Dúbravská cesta 9, 841 04 Bratislava, Slovakia, veliskova@uh.savba.sk; ORCID iD 0000-0002-3667-2023
[2)] Institute of Hydrology, Slovak Academy of Sciences, Dúbravská cesta 9, 841 04 Bratislava, Slovakia, bara@uh.savba.sk; ORCID iD 0000-0002-3635-1879
[3)] Institute of Hydrology, Slovak Academy of Sciences, Dúbravská cesta 9, 841 04 Bratislava, Slovakia, sokac@uh.savba.sk; ORCID iD 0000-0002-8036-1951

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Abstract

Water is an integral part of the Earth's environment. Its availability, and therefore its usability in space and time from a social and economic point of view, is connected not only with its quantity, but also with its quality. Supplying the population with drinking water is an important, even key, task, the weight and importance of which are growing even more in the face of ongoing climate change. To ensure this task, underground water sources are primarily used; in the event of a shortage, water reservoirs are often used. In Slovakia, 7 reservoirs are currently used for these purposes. One of them is the Hriňová water reservoir in central Slovakia. The reservoir's total volume is approximately 7.4 million m3 of water. Given the reservoir's primary purpose, it is necessary to monitor water quality indicators in it. One of the objectives of the national project APVV-22-0610 is also to monitor basic water quality indicators in this reservoir to track seasonal changes in their values and determine the processes occurring in the reservoir. The measurements were carried out in spring, summer and autumn. In this article, the measurements of water temperature in the three seasons were evaluated. The results of the 2025 campaign show that the measurement in the spring (April 2025) took place at the beginning of the spring water circulation in the reservoir. The water temperature ranged from 4.9 °C at the bottom to 13.4 °C at the surface, with the temperature profile along the depth being similar in deeper verticals. The vertical from the shallower part of the reservoir – with a depth of up to 10 m – showed greater water overheating. The maximum temperature gradients were in the depth range of 2-6 m, in the shallower area 4-8 m. In the summer (July 2025), the measurement results indicated the formation of a temperature stratification to a depth of approximately 20 m in the deeper areas of the reservoir, and, in the shallower areas, throughout the entire depth. The water temperature ranged from 6.2 °C at the bottom to 22.3 °C at the surface, with the temperature profile along depth similar across all verticals. The maximum temperature gradients occurred at depths of 5-10 m. In the autumn period (November 2025), measurements were taken when the autumn circulation was almost complete - the water temperature along the depth was balanced with a value of (8.8-9) °C up to the 20 m horizon. The water temperature from this depth to the bottom changed not very significantly (by 1 °C in total). These interim results, despite everything, provide basic information about the temperature stratification of water in this water reservoir and indicate other processes related to the development of water quality in this water body, which will be the subject of further research, which should contribute to more efficient handling of water resources intended for supplying the population with drinking water.

Keywords: *water reservoir, water temperature, thermal stratification, seasonal changes*

1. Introduction

Water reservoirs are one of the vital parts of the world's freshwater sources, serving purposes like providing drinking water, supporting agriculture and industry, controlling floods, and maintaining ecosystems. Ensuring high water quality in these reservoirs is essential for protecting public health, ecological balance, and sustainable water use. Water quality in reservoirs varies significantly across time and their space, influenced by hydrodynamic forces, climate, anthropological and biological activity [1, 2]. Typically, horizontal differences are minimal under stable conditions, but vertical variations can be pronounced, especially during thermal stratification [3]. In temperate zones, seasonal patterns of summer stratification and spring and fall turnover greatly affect key water quality indicators, including temperature, dissolved oxygen, pH, and electrical conductivity [4, 5].

In recent decades, climate change has emerged as a significant factor impacting reservoir ecosystems by modifying hydrological regimes and physicochemical processes within aquatic environments [5, 6, 7]. Rising air temperatures, shifting precipitation patterns, and the increasing frequency of extreme events such as droughts and floods profoundly affect both water quantity and quality [8]. Research conducted in Slovakia and globally has demonstrated that reservoir water quality is influenced by the combined effects of climatic variability, land use, and management practices, underscoring the necessity for comprehensive monitoring programs and adaptive management strategies [1, 2, 5, 9].

Thermal stratification is a key process influencing reservoir water quality. It arises from temperature-induced density differences within the water column, resulting in distinct layers: the epilimnion, the metalimnion (thermocline), and the hypolimnion (see Fig. 1). Each layer has unique physical and chemical traits [3, 4]. By limiting vertical mixing and material exchange, stratification significantly affects the distribution of dissolved oxygen, nutrients, pH, and other water quality parameters. In temperate regions like Slovakia, stratification usually occurs in late spring, peaks during summer, and partially or fully breaks down in autumn.

Recent research indicates that climate warming is affecting stratification dynamics by extending its duration, increasing its intensity, and enhancing its stability [5, 7, 10]. Thermal stratification tends to start earlier in spring and last longer into autumn in many temperate water bodies [8]. As a result, the frequency and strength of complete mixing events—which are crucial for

distributing oxygen and nutrients throughout the water column—are shifting. These changes could have significant impacts on water quality, especially in the deeper layers of reservoirs. Long-term studies of the Turček and Rozgrund reservoirs in Slovakia have documented notable seasonal stratification, with a well-formed thermocline during summer and increasingly variable autumn turnover patterns [11, 12].

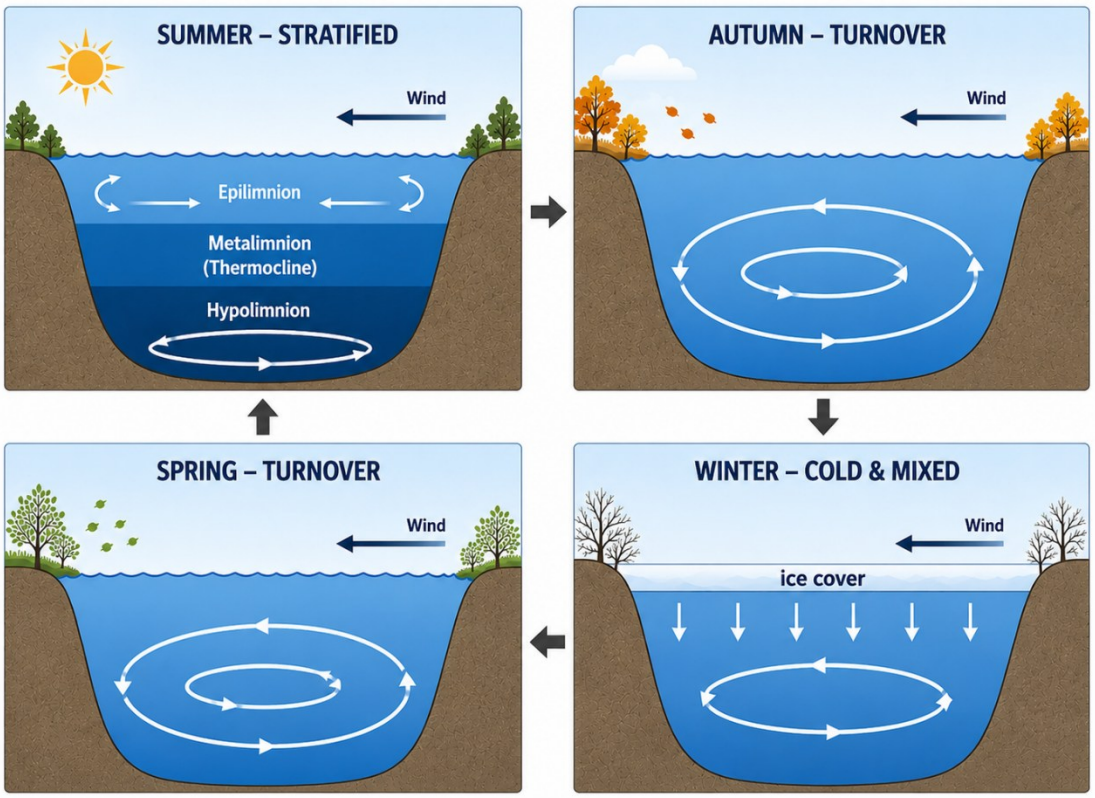

Fig. 1 Annual circulation patterns in the Hriňová Water Reservoir

Climate change projections indicate that thermal stratification will become more persistent in many reservoirs as a result of rising air temperatures and changing hydrological patterns. Both observational data and models show that warmer surface waters increase the stability of stratified layers, raising the risk of oxygen depletion in deeper waters and potentially disrupting ecosystems [13]. Likewise, Azadi et al. [14] found that under climate change, thermal stratification first appears in shallow layers during spring and summer but can penetrate deeper in autumn, while complete mixing remains possible in winter. These shifts can lead to hypoxic or anoxic zones, harming aquatic life and degrading water quality.

2. Description of the study locality

For the study, the Hriňová water reservoir in central Slovakia was selected (Fig. 2). The reservoir is located in a mountainous, forested area, at the locality of confluence of the Hukava River and the Slatina River. It is situated around 560 m a.s.l. The dam was built on the Slatina River (the Hron River basin) at r. km 47.850 in the immediate vicinity above the town of Hriňová. The reservoir's total volume is approximately 7.4 million m^3 of water.

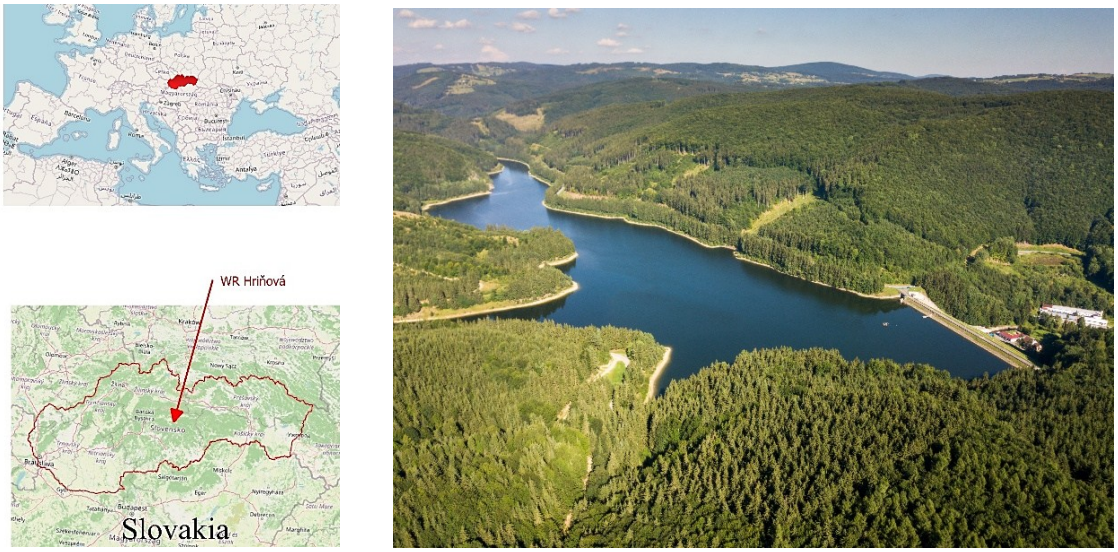

Fig. 2. Localisation and aerial photo of the Hriňová Water Reservoir (photo reproduced with permission of Slovenský Vodohospodársky Podnik, štátny podnik – waterwork administrator).

The minimum operating level is 539.60 m a.s.l., the maximum operating level is 565.20 m a.s.l. The maximum water depth is 39 m. The dam creating this reservoir is rocky with an internal inclined and upper vertical seal (the choice was given by the complicated geology - granodiorites, mylonites) and with a height of 41.5 m. Construction took place in the first half of the 1960s, with the main purpose of ensuring drinking water supply to the population for the Hriňová–Lučenec–Fiľakovo group water supply system. In addition, the reservoir ensures minimum flow rates in the Slatina River below it, supports fish farming, and uses the existing hydropower potential through built-in small hydropower plants. Due to persistent structural and operational problems, the Hriňová water reservoir was only put into permanent continuous operation in 1998.

Slovakia lies in the temperate climate zone. Within Slovakia, the Hriňová reservoir is located in a moderately warm, very humid climatic region with cold winters. This area is characterised by an average annual air temperature of 6 to 7 °C, average annual precipitation of 700 to 800 mm and average annual potential evapotranspiration of 450 to 500 mm [15].

The quality of surface water sources for drinking water is sensitive to impacts from their catchments. Therefore, water supply reservoirs in Slovakia are surrounded by sanitary protective zones where special restrictions and prohibitions apply (e.g., regarding agricultural activity, forestry and environmental restrictions) to ensure good ecological status of water resources [9].

3. Measuring the water temperature and thermal stratification of water reservoirs

Given the reservoir's primary purpose is water supply, it is necessary to monitor water quality indicators in it. One of the objectives of the national project APVV-22-0610 is also to monitor basic water quality indicators in this reservoir to track seasonal changes in their values and determine the processes occurring in the reservoir. The measurements were conducted three times annually - during spring, summer, and autumn — with winter excluded due to the freezing of the water surface - across several vertical profiles. Water temperature was recorded every 2 meters at depths less than 20 meters and every 5 meters at depths exceeding 20 meters, extending to the bottom within the vertical profiles. At each profile and depth, temperature measurements were taken three times, and the average value was subsequently calculated. All measurements were performed from a boat utilising a portable multiparametric probe, the WTW Digital Multi 3630 (see Fig. 3). The spatial distribution of the measured verticals was determined based on previous bathymetric measurements to ensure a representative spatial distribution and is illustrated in Fig. 4.

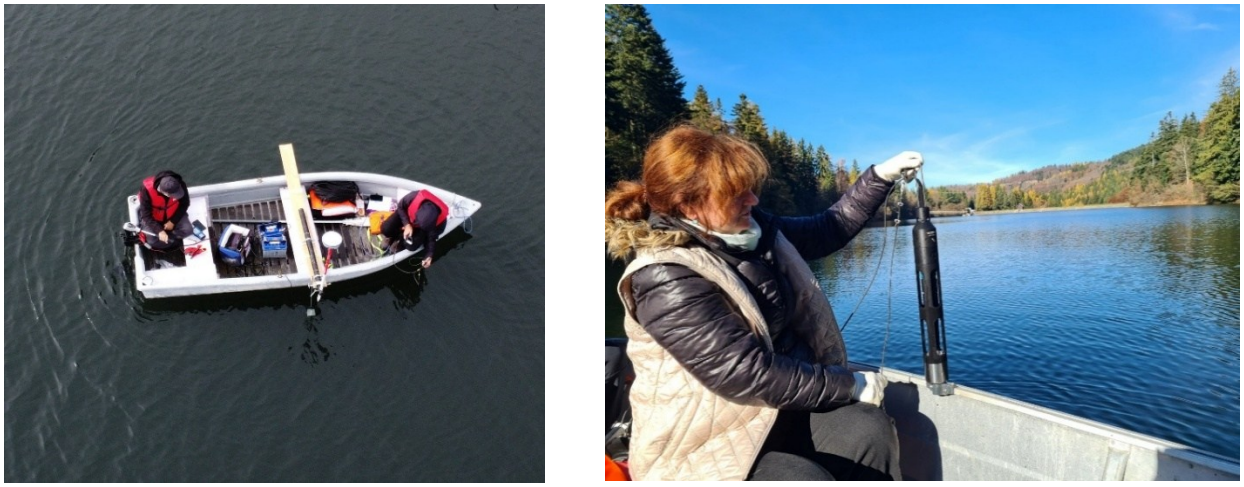

Fig. 3. Photos from measurements at the Hriňová Water Reservoir (photo source: authors).

Fig. 4. Locations of the measured verticals at the Hriňová Water Reservoir

4. Results and discussion

Deep lakes and water reservoirs (with depths greater than 10 m) are characterised by the development of vertical stratification, with several important features often displaying significant seasonal variation. Water temperature is the most important variable, and seasonal and vertical differences in temperature influence other physicochemical properties in water bodies.

Various thermal patterns are common in deep-water reservoirs. Regarding the measurement results, we can say that the Hriňová water reservoir exhibits a dimictic thermal pattern, i.e. two periods of mixing per year, in spring and autumn, caused by seasonal temperature differences and wind mixing effects (as it can be seen on Fig. 1). It means that in summer, the water column stratifies, and a strong vertical temperature (and density) gradient develops the easily wind-mixed, warmed-up surface water layer and the deeper, colder water masses. During this process, water bodies are divided into three layers at different temperatures and densities: epilimnion, metalimnion and hypolimnion layers [16]. The surface water (epilimnion) stops mixing with the lowest layer (hypolimnion). The boundary between these layers is the metalimnion, a zone of rapid temperature change. With the onset of autumn, the epilimnion cools, becoming denser and sinking to mix with the hypolimnion. Wind provides the energy needed to mix the two layers, causing the lake to circulate, or overturn, completely [17]. This circulation continues until the surface ice protects the lake from further wind action. The lake overturns again in the spring when the surface ice melts. By summer, the lake will be stratified once again (Fig. 1).

As mentioned above, the results of the 2025 campaign (see Fig. 5) show that the Hriňová water reservoir exhibits dimictic thermal behaviour. The measurement in the spring (April 2025) was performed at the beginning of the spring water circulation in the reservoir. The water temperature ranged from 4.9 °C at the bottom to 13.4 °C at the surface, with the temperature profile along depth being similar in the deeper parts of the reservoir. However, the vertical from the shallower part of the reservoir – with a depth of up to 10 m – showed greater water overheating. The maximum temperature gradients were in the depth range of 2-6 m, in the shallower area 4-8 m. In the summer (July 2025), the measurement results indicated the formation of a temperature stratification to a depth of approximately 20 m in the deeper areas of the reservoir and throughout the entire depth in the shallower areas. The water temperature ranged from 6.2 °C at the bottom to 22.3 °C at the surface, with the temperature profile along depth similar across all verticals. The maximum temperature gradients occurred at depths of 5-10 m. In the autumn period (November 2025), measurements were taken when the autumn circulation was almost complete - the water temperature along the depth was balanced with a value of (8.8-9) °C up to the 20 m horizon. The water temperature from this depth to the bottom changed not very significantly (by 1 °C in total).

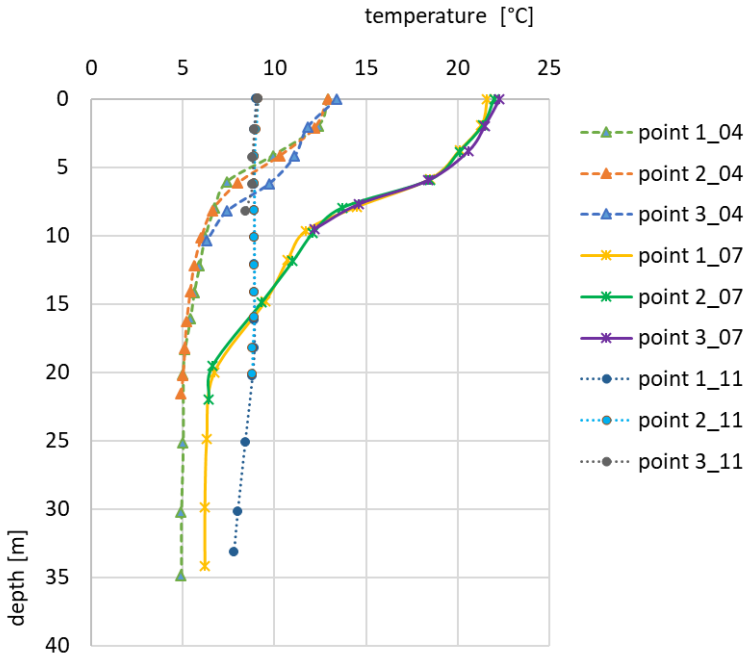

Fig. 5. Water temperature course in the measured verticals at the Hriňová water reservoir (in 2025)

5. Conclusion

The paper summarised and analysed the results of one year water temperature monitoring at the Hriňová water reservoir. The results confirm that this reservoir has a dimictic thermal pattern, with a relatively early onset of thermal stratification of water. The maximum temperature gradients during this period were at depths of 2-6 m, and in the shallower area at 4-8 m. In the summer period, this change shifted to a depth of 5-10 m and was uniform across the entire reservoir. Measurements in November showed the disappearance of this stratification.

Despite their simplicity, these interim results provide basic information on the temperature stratification of water in this reservoir and indicate other processes related to the development of water quality in this water body. Anyway, it will be necessary to continue such monitoring and analysis as the subject of further research, which should contribute to more efficient handling of water resources intended for supplying the population with drinking water.

Acknowledgments

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References

1. D. D. Poudel, T. Lee, R. Srinivasan, K. Abbaspour & C.Y. Jeong "Assessment of seasonal and spatial variation of surface water quality, identification of factors associated with water quality variability, and the modeling of critical nonpoint source pollution areas in an agricultural watershed, Journal of Soil and Water Conservation, 68:3, 155-171, (2013) https://doi.org/10.2489/jswc.68.3.155
2. S. M. Lopes, N. M. B. de Arruda, T. A. Pagioro "Study of the stratification process at the reservoir of the hydroelectric power plant Gov. Pedro Viriato Parigot de Souza (Capivari-Cachoeira), Paraná, Brazil ", Ecletica Quimica, 43(2), 23–31 (2018). https://doi.org/10.26850/1678-4618eqj.v43.2.2018.p23-31
3. R. G. Wetzel. "Limnology: Lake and river ecosystems" (3rd ed.). Academic Press. (2001) https://www.scribd.com/document/559820988/WETZEL-Robert-G-Limnology-Lake-and-River-Ecosystems
4. J. Kalff. "Limnology: Inland water ecosystems". Prentice Hall, Upper Saddle River, New Jersey 07458 (2002) https://livresbioapp.wordpress.com/wp-content/uploads/2016/03/limnology-kalff.pdf
5. R. Roberto, A. Ahmed, B. Van Wesenbeeck, Deg-Hyo Bae, G. Filippo, G. Grossi, G. Nalder, Hyun-Han Kwon, I. J. Losada, J. L. Lara, K. Kobayashi, R. Teegavarapu, T. Silva, Van-Thanh-Van Nguyen, Y. Jia. "Guidance for Water Engineering in a Changing Climate". IAHR Water Monograph Series. Published by International Association for Hydro-Environment Engineering and Research (2025), 181 p. ISBN (electronic): 978-90-835589-4-3. https://www.iahr.org/library/infor?pid=34349
6. C. M. O'Reilly, S. Sharma, D. K. Gray, S. E. Hampton, J. S. Read, R. J. Rowley, P. Schneider, J. D. Lenters, P. B. McIntyre, B. M. Kraemer, G. A. Weyhenmeyer, D. Straile, B. Dong, R. Adrian, M. G. Allan, O. Anneville, L. Arvola, J. Austin, J. L. Bailey, ….G. Zhang. "Rapid and highly variable warming of lake surface waters around the globe". Geophysical Research Letters, 42(24), 10,773–10,781. (2015). https://doi.org/10.1002/2015GL066235
7. M. Kumagai. "Effect of global warming on a deep lake and mitigation measures" (2024) [Online]. Available from https://www.iahr.org/library/download-paper-file?code=DHBtgXPWvU
8. R. I. Woolway, C. J. Merchant. "Worldwide alteration of lake mixing regimes in response to climate change." Nature Geoscience, 12(4), pp. 271–276. (2019) https://doi.org/10.1038/s41561-019-0322-x
9. M. Trenčiansky, K. Báliková, M. Štěrbová, J. Šálka. Current Issues and Challenges in Slovak Water Reservoir Management. *Water*, 17(17), 2521. (2025). https://doi.org/10.3390/w17172521
10. J. Shi, L. Wang, Y. Yang, T. Huang. "A case study of thermal and chemical stratification in a drinking water reservoir", Science of The Total Environment, Volume 848, 157787, (2022). https://doi.org/10.1016/j.scitotenv.2022.157787
11. A. Varga, Y. Velísková, M. Sokáč, V. Sočuvka, P. Mikula. "Analysis of seasonal changes of thermal stratification in reservoir for drinking water supply (Slovakia, Turček reservoir)". Acta Hydrologica Slovaca, 24 (1), 2023, pp. 33–42, (2023) https://doi.org/10.31577/ahs-2023-0024.01.0005
12. Y. Velísková, V. Sočuvka, M. Sokáč, M. Koczka Bara, S. Okhravi. "Changes of thermocline in two different reservoirs for drinking water supply in Slovakia". In 18th International Symposium on Water Management and Hydraulic Engineering (WMHE 2024): Symposium Proceedings, Bratislava, Slovak University of Technology in Bratislava in SPEKTRUM STU Publishing, pp. 400-409. (2024)
13. B. Ma, F. Dong, W. Peng, X. Liu, A. Huang. "Dynamics of oxygen evolution in a thermally stratified reservoir under climate warming". Scientific Reports, 15, 40419. (2025). https://doi.org/10.1038/s41598-025-13432-2
14. F. Azadi, P.-S. Ashofteh, X. Chu. "Evaluation of the effects of climate change on thermal stratification of reservoirs", *Sustainable Cities and Society*, Volume 66, 102531, (2021) https://doi.org/10.1016/j.scs.2020.102531
15. Climate Atlas of Slovakia, Slovak Hydrometeorological Institute, Bratislava, 2015, 132 p.
16. B. Boehrer, M. Schultze . Stratification of lakes*, Rev. Geophys*., 46, RG2005, (2008) doi:10.1029/2006RG000210
17. P. Fafard. "How and Why Lakes Stratify and Turn Over: We explain the science behind the phenomena", Published by IISD [online], (2018). https://www.iisd.org/ela/blog/lakes-stratify-turn-explain-science-behind-phenomena/