

Special issue dedicated to 70th anniversary of foundation of Institute of Hydrology, Slovak Academy of Sciences, Bratislava, Slovakia

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Dear readers,

You receive to your hands an issue of the Journal of Hydrology and Hydromechanics (JHH) dedicated specially to the 70th anniversary of the founding of the Institute of Hydrology, Slovak Academy of Sciences (IH SAS), which is currently its publisher. I think it is a good opportunity to recap briefly the history of our Institute, as well as the history of the Journal of Hydrology and Hydromechanics itself. Many facts were summarised and mentioned on the 65th anniversary of the institute, however, repetition is the mother of wisdom, and besides, these milestones in the history of the institute and the journal deserve to be repeated.

The necessity to understand basic laws of water cycle as a precondition to improve water management of Slovakia was the reason of establishing the Institute of Hydrology, Slovak Academy of Sciences (SAS). The resolution of the Presidium of the Slovak Academy of Sciences in 1953 established the institute as the Water Management Laboratory of SAS. Founder of the Institute – and its first director – was Prof. Dr. Oto Dub. Since then eight people have held the position of director of the Institute. There are: Prof. E. Mäsiar (1963–1974), Prof. M. Dzubák (1974–1981), Prof. J. Benetin (1981–1990), Dr. K. Kosorin (1990–1991), Dr. J. Šútor (1991–2004), Dr. V. Štekauerová (2004–2012), Dr. P. Pekárová (2012–2016) and me (2016–up to now).

The aim of the Water Management Laboratory of SAS was to develop theoretical hydrology and solution of actual problems related to surface and subsurface water. In 1959 the Water Management Laboratory was renamed (again by the resolution of the Presidium of SAS) to the Institute of Hydrology and Hydrotechnics SAS. The relatively good equipment for the theoretical and experimental studies was reflected in many research activities. Since 1963 Presidium of SAS decided to change the name of the institution again according to its new tasks. Its new name - Institute of Hydrology and Hydraulics SAS – better represented its research topics. It is necessary to mention the year 1989, after which significant changes of the Institute were performed. The staff number decreased from 108 to 50 and funding of the Institute was changed from budgetary to those which activity are covered from the state budget only partially (since 1993). To characterize contemporary institutes activity focused to hydrology, its name has been changed to the Institute of Hydrology SAS since 1993. The last significant change took place in 2022, when the Institute of Hydrology SAS was transformed into the form of a public research institution.

Institute of Hydrology SAS is now a scientific research institution which conducts a comprehensive research and teaching in the field of environmental science and water management to improve and disseminate knowledge on the circulation and quality of water in the nature. The activity of the Institute is focused on:

- water balance components and their changes in catchments;
- transport processes of water and dissolved matters in the atmosphere–plant canopy–soil water–groundwater system with special focus on the subsurface water formation and its quality;
- flow of surface water, groundwater and transported substances;
- impact of human activities on hydrological processes, including processes of surface and subsurface water pollution;
- changes in hydrological regime of surface and subsurface waters caused by expected climatic changes both in natural and urban catchments;
- solving problems connected with environmental management, ecology, utilization and protection of environment, hydrogeology, pedology;
- solving problems connected with water constructions and their impact on the environment, hydromeliocracy, hydrotechnical applications, water modifications, flood protection, water morphology, integrated water management, water planning and water resources protection;
- solving problems connected with landscape engineering, plants and soil protection and with securing water supply during drought seasons.

The Institute provides consultancy and expertise services related to its main activity and also performs PhD study in accordance to valid legal regulations.

Since its establishment, the mission of the Institute of Hydrology SAS is the acquirement and transfer of new scientific knowledge in the fields of hydrology, hydrodynamics and water hydraulics to water management practise, mainly in Slovakia. The Institute elaborates methodologies and manuals to provide the society with powerful tools to solve urgent and perspective water-related problems using the contemporary scientific knowledge. Simulation models are designed and used in analyses and predictions of water dynamics and quality. Special attention is paid to building databases of input data characterizing the regions of Slovakia.

Different sub-disciplines of hydrology are using specific methodological approaches and equipment; this is reflected even in structure of the Institute. Institute is divided into two departments:

- Department of Surface Water Hydrology,
- Department of Subsurface Water Hydrology.

Territory of Slovakia is morphologically diversified and research under different natural conditions needs specific methodology and equipment. There was one of reasons to establish remoted workplaces for particular regions, which are focused on research in the field conditions:

- Research Base of Mountain Hydrology, Liptovský Mikuláš, (research of water movement and runoff formation in condition of mountainous catchments),
- Research Base of Lowland Hydrology, Michalovce (soil hydrology of lowlands, with accent to East Slovakia Lowland).

The aim of research conducted by the Institute of Hydrology SAS is to acquire new knowledge about quantitative and qualitative characteristics of water movement in ecosystems influenced by human activity and global changes (climate change is one of many global changes).

Those goals can be reached by the combined laboratory and field activities; field research is the source of primary information about the system and allows designing mathematical and simulation models and its results can be used for their validation.

One of the significant acts of the Institute of Hydrology SAS is the creation, management and publishing of the Journal of Hydrology and Hydromechanics. History of this journal reached or is linked with the establishment of the Institute. The first volume of the journal antecedent, which name at that time was the *Vodohospodársky časopis*, was published in 1953, when the Institute was founded, and contained one double-number. Since 1955 the journal was edited quarterly and since 1969 in 6 issues per year. Since 1961, the journal is issued by the Institute of Hydrology SAS (Slovakia) in co-operation with the Institute of Hydrodynamics AS CR (Czech Republic) which ended due to the decision of this partner in 2021. During the years the quality of journal has increased, from relatively modest beginnings with small group of authors and subscribers up to the significant international journal. Since 1993, the *Vodohospodársky časopis* began to be published by the variant name the Journal of Hydrology and Hydromechanics. In 2003 the Journal changed definitely its name to the today's form: Journal of Hydrology and Hydromechanics and started to be edited quarterly again. Nowadays, the journal is an international open access journal for the basic disciplines of water sciences. The scope of hydrology is limited to biohydrology, catchment hydrology and vadose zone hydrology, primarily of temperate zone. The hydromechanics covers theoretical, experimental and computational hydraulics and fluid mechanics in various fields, two- and multiphase flows, including non-Newtonian flow, and new frontiers in hydraulics. The Journal publishes original research papers, short communications/technical notes, and reviews that have been thoroughly peer reviewed. Hundreds of papers published in the journal prove that, within the mentioned scientific disciplines, it has become an important mediator of research results from all over the world.

This special issue summarizes and presents latest results of cooperation among researchers from the Institute of Hydrology SAS and from other research institutions. This issue includes papers from more than 50 authors from 11 European countries. It was put together for the communication of contributions to the current state of hydrology, vadose zone hydrology and hydromechanics in connection with the topics dealt with at the Institute of Hydrology SAS.

In recent years, the application of biochar in soils is considered a beneficial strategy for improving soil ecosystem services. Botková et al. (this issue) deal with biochar, as an organic amendment, which can positively change soil properties, especially soil with low organic matter and/or poor structure. Both biochar type and particle size affect the soil hydro-physical parameters. Results of study of two different types of biochar and three particle sizes show the most effective treatment for sandy soil was proved by the biochar produced from willow with

the smallest particle size (<125 µm). The objective of the study of Rončák et al. (this issue) was the evaluation of differences in the soil erosion of silt loam soil with or without the application of biochar and the comparison of the impact of biochar application on soil erosion for different agricultural practices. Several scenarios were simulated by 3D model EROSION and the impact of the application of biochar on soil erosion was assessed. The effect of biochar application on reducing soil erosion was demonstrated for all types of agricultural practices. Anyway, further research is needed to gain a deeper understanding of its total effects to this process.

In heavy soils, changes in humidity incur soil volume changes. In the horizontal plane, these are manifested by cracks formation and in the vertical plane by the movement of the soil surface. Cracks have a significant impact on hydrodynamics of the soil profile. The work Gomboš et al. (this issue) is based on the hypothesis that soil volume changes depend on both the content of clay particles in soil and soil volumetric moisture. The aim of the work was to measure and analyze the changes in the width of the cracks and their reaction to the changes in volumetric soil moisture. For the study of crack width, a soil profile in an area on the East Slovakia Lowland was selected, which is the typical area with heavy soils. One of the objectives of the work was also to design a simple tool for accurate measurement and calculation of the crack width on the soil surface.

Climate change is presently a widely discussed subject in relation to alterations in water storage capacity and the components of the hydrological balance within catchment areas. The studies Pekárová et al. (this issue) demonstrate part of such results connecting with Danube River Region. The aim of the first one was to analyse changes and predict the course of mean monthly water temperatures of the Danube River at various locations for the future. The second study was focused on the possibility and sensitivity of indirect estimation of long-term mean annual runoff using an empirical model and on determination of changes in the annual runoff regime of fifty Danube sub-basins. To assess the impact of future climate on stream temperatures, the historical long-term average of the monthly water temperature (1990–2020) was compared with scenarios S1 (2041–2070) and S2 (2071–2100) by using Seasonal Autoregressive Integrated Moving Average (SARIMA) models and nonlinear regression models (NonL). The simulation results from the two stochastic models showed that in scenario S1, the Danube River's average monthly water temperature is projected to increase by 0.81/0.82 °C (Passau), 0.55/0.71 °C (Bratislava), and 0.68/0.56 °C (Reni). In scenario S2, the models predict higher increases: 2.83/2.50 °C (Passau), 2.06/2.46 °C (Bratislava), and 2.52/1.90 °C (Reni). Overall, the SARIMA model proved to be more stable and effective in simulating the increase in monthly water temperatures in the Danube River. Regarding sensitivity of runoff due to changes in the characteristics of the water balance in the Danube River region, the results suggest that a 100 mm increase in the average annual rainfall in the Danube River headwater sub-basins will cause a 50 mm increase in outflow and a 1 °C increase in the average annual air temperature will lead to a 12 mm decrease in runoff.

Evaluation of precipitation measurements using a standard rain gauge in relation to data from a precision lysimeter is the topic of the paper by Tall et al. (this issue). The construction of modern lysimeters with a precise weighing system made it possible to achieve an unprecedented accuracy of precipitation measurement. This study compared two methods of measuring precipitation in the conditions of the humid continental climate

of the Eastern Slovakian Lowland (Slovakia): measurement using a standard tipping-bucket rain gauge vs. precision weighable lysimeter. The comparison period lasted four years (2019–2022). Cumulative precipitation for the entire monitored period captured by the rain gauge was 2.8% lower compared to lysimeter measurements. When comparing hourly and daily totals of precipitation and precipitation events, a very high degree of agreement was detected ($r^2 > 0.99$; RMSE from 0.22 to 0.51 mm h⁻¹). A comparison based on precipitation intensity showed a decreasing trend in measurement accuracy with increasing precipitation intensity.

Water loss to the atmosphere occurs through the process of evapotranspiration, which involves the evaporation from different surfaces and the transpiration of water through plants. It is a crucial water cycle component in the Earth's climate system. Computing reference evapotranspiration (ET_o) is an essential step in the evaluation of the water balance in catchments. The Food and Agriculture Organization (FAO) provides a widely used method for calculating ET_o based on several meteorological variables, including temperature, humidity, wind speed, and solar radiation. However, the availability of these variables is often limited in many regions, making it challenging to estimate ET_o accurately. The study of Považanová et al. (this issue) offers the possible use of machine learning (ML) and feature engineering (FE) techniques to accurately determine FAO reference evapotranspiration (ET_o) with a minimal number of climate variables being measured. The recommended techniques for areas with insufficient measurements are based solely on daily temperature readings. Various ML methods were tested to evaluate how sophisticated an ML algorithm is for this task necessary. ML methods, mainly due to the transformation of raw variables using FE, provided better results than traditional empirical methods and sophisticated ML algorithms without FE. The potential of this approach to deliver improved predictions, reduced input requirements, and increased efficiency holds interesting promise for optimizing water management strategies, irrigation planning, and decision-making within the agricultural sector.

Some researchers of the Institute of Hydrology SAS in collaboration with foreign colleagues focused their interest to the specific problems of mountain hydrology. In the study of Sleziak et al. (this issue), the MIKE SHE spatially distributed hydrological model was used as a diagnostic tool to provide information of possible areas of overland flow sources in the mountain basin of Jalovecký Creek (area 22.2 km², height range 820–2178 m a.s.l.) during different rainfall-runoff events. Selected events represented a sequence of several smaller, consecutive events, a flash flood event and two large events caused by frontal precipitation. Simulation of hourly runoff was better for runoff events caused by heavy rainfalls of longer duration than for the flash flood or consecutive smaller runoff events. Higher soil moisture was simulated near the streamflow network and larger possibly saturated areas were located mainly in the upper parts of mountain valleys. The most pronounced increase in the areal extent of possibly saturated areas (from 6.5% to 68.6% of the catchment area) was simulated for the event with high peak discharge divided by a short rainfall interruption. Rainfall depth exceeding 100 mm caused a large increase in the potentially saturated areas that covered subsequently half of the catchment area or more.

Intense floods represent a challenge to risk management. Classical frequency analyses, which establish a relation between the peak flow or volume and the frequency of exceedance, may lead to improper risk estimations and mitigations. It is necessary to study floods as multivariate stochastic events having mutually

correlated characteristics, such as peak flood flow, corresponding volume and duration. The joint distribution properties of these characteristics play an important role in the assessment of flood risk and reservoir safety evaluation. The paper by Výleta et al. (this issue) provided risk analysis with a consistent multivariate probabilistic framework using a copula based approach. The framework respects and describes the dependence structures among the flood peaks, volumes, and durations of observed and synthetic control flood hydrographs. The seasonality of flood generation is respected by separate analyses of floods in the summer and winter seasons. The proposed multivariate probabilistic framework was tested and demonstrated based on data from two contrasting catchments in Slovakia. Based on the findings, the study affirms that the trivariate copula-based approach is a practical option for assessing flood risks and for reservoir safety.

When solving water flow problems, whether within the framework of a basin or a stream, it is appropriate to know also the hydrodynamic aspect of the problem. The research of Okhravi et al. (this issue) is oriented on flow resistance at lowland and mountainous rivers. The study examines the various sources of flow resistance in sand-bed (lowland) and gravel-bed (mountainous) rivers along with the limitations of traditional estimation methods. The nondimensional hydraulic geometry approach, relating dimensionless flow discharge to the Darcy-Weisbach friction factor, has demonstrated good performance for both river types, covering shallow to moderately deep flows. The proposed method is evaluated using data from four sand-bed rivers in Slovakia, and three gravel-bed rivers in Iran. The method is further validated using published field data and established equations from rivers with similar physiographic characteristics. Results indicate the method performs well in predicting flow resistance in sand-bed rivers. However, the predictor's validity for gravel-bed rivers is somewhat limited due to high variability in water-surface profiles, making it challenging to accurately capture flow dynamics under large-scale roughness conditions.

A very common problem encountered these days is the contamination of water bodies through various anthropogenic activities. To date, thousands of water pollution incidents caused by accident or illegal emissions have happened all around the world, which cause serious threats of the environment and public health. Understanding of mass transport processes is a very important step in solving water quality problems and their changes in time and space. Hydrodynamic approach often uses the advection-dispersion equation (ADE) for this kind of task, but in general, direct application of this equation allows predicting mass spreading in downstream direction from a known source in a known location. The paper by Velísková et al. (this issue) deals with specific problem: the pollutant source localisation in streams in other words the solution of the inverse problem of pollution spreading with in an extensive open channel network structure, i.e. in a complex system of rivers, channels and creeks in natural catchments or sewer systems in urban catchments. The design of the overall localisation procedure was based on the requirement that the entire localization system be operative and fast enough to enable quick operative interventions and help prevent the spread of pollution. The proposed model, as well as, the overall localisation procedure was calibrated and tested on a real sewer system, which represented in this case an extensive open channel network structure with free surface flow. The test results were successful and confirmed applicability of proposed localization tool in simple real conditions.

Hydrology and hydrodynamics are important sciences for society because they deal with water resources that are essential

for life, the economy and the environment. Topics of the papers in this issue confirm that hydrological sciences is a multidisciplinary and interdisciplinary field that brings together different aspects, scientific disciplines and applies them to solving water-related problems.

Mentioned collection of original articles represents dissemination outcomes of national and international cooperation activities of the Institute of Hydrology SAS. I would like to thank

all authors for their contributions, as well as, all handling editors, namely Radka Kodešová, Václav Matoušek and Juraj Parajka.

I wish the readers of Journal of Hydrology and Hydromechanics a pleasant time with procurement of next knowledge and a lot of new inspiration.

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