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MONITORING AND INVESTIGATION OF INTERMITTENT RIVERS IN BULGARIA

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River flows could be defined according to their surface hydrologic stream duration as either perennial or temporary. Normally perennial streams flow throughout the year, while temporary streams lack surface flow for some periods of the year. Temporary streams are classified as intermittent or ephemeral. Intermittent streams flow in some periods as result of snowmelt and eventually elevated
groundwater tables during the periods of increased precipitations.

At the watershed scale intermittent streams usually are a part of the channel network, mainly as first and second order rivers. As tributaries to larger rivers they play a significant role in the dynamics of materials and energy at the watersheds. Intermittent streams are poorly represented in existing river monitoring programs in Bulgaria and very seldom are objects of regular monitoring. Only in several gauging stations exist hydrological historic time series. Furthermore, intermittent and ephemeral streams are not adequately protected by current legislation and management strategies in Bulgaria and generally are neglected.

The authors discuss the climatic, hydrological and soil conditions in different part of the country as the major factors determining their origin and distribution. Covering the whole territory of Bulgaria the authors identify four main types of intermittent streams as: 1) intermittent flows as result of Mediterranean climatic impact located in the southern part of the country; 2) sinking intermittent flows as result of specific geological and soil characteristics, 3) intermittent flows in large karst and loess areas and finally 4) the sinking flows in alluvium depositions mainly along the large mainstreams. Nevertheless, the limited number of gauging stations built up at these rivers some hydrological information is collected and statistical results are presented as duration curves of temporal rivers, hydrographs with seasonal characteristics etc.

Intermittent streams have a hydrologic flow regime with very specific characteristics that place them as interact between land and water. Unfortunately, in Bulgaria there are poorly mapped, recognized, and protected but they have a critical influence on the ecological health of networks. There exists a strong need for new approaches to scientifically study, the structure and function of temporal streams. The construction of monitoring network for the regular registration of their hydrological regime is surely the first required step for their future detailed ingestions, use and protection.

Keywords: intermittent rivers, mapping, regime, hydrology

MONITORING AND EVALUATION OF GROUNDWATER LEVELS AT LADNÁ HYDROPEDOLOGICAL PROFILE

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The planned construction of Oder-Danube canal was one of the largest activities, which led to realization of research projects, which also included construction of boreholes for monitoring groundwater levels. The area of potential navigability of the rivers Morava and Oder (Odra) and route of the planned canal connecting Danube-Oder-Elbe has been protected since 1996 within zoning plans of larger territorial units. This would also fulfil the original goal of monitoring long-term time series of groundwater levels. Hydropedological profiles (HP) consist of boreholes, which are situated usually across the route of the canal and also across longitudinal axis of valleys or flat Moravian valleys. They belong to basins of Oder, Bečva, Thaya (Dyje) and Morava rivers. First observations began back in 1933 and 1934, subsequent followed after 1940. Nowadays these objects serve for general idea about the groundwater regime in valley profiles of these rivers. From geological perspective, they are HP profiles in an area of Quaternary sediments. The particular areas with profiles consist of mostly lighter soils, sandy soils and slightly clay and loose sands.

Ladná, the profile of interest, is located north of Břeclav, passes through cadastral area of Charvatská Nová Ves and ends on the outskirts of the Lednice city. It is 4.98 km long and crosses the Thaya, Trkmanka and Včelínek rivers. It was built in 1948 and therefore has a 70-years long continuous monitoring series. Over time the location underwent several changes, most importantly the construction of the Nové Mlýny dam and modification of the Thaya riverbed. Evaluation of the Hydropedological profile will utilize basic statistical methods for large dataset analysis. Dynamics of the groundwater level is assessed in the context of time and relationship with surface water levels, precipitation and geological profile during various reference periods. The obtained findings from the individual reference periods are analyzed and thoroughly assessed. One of the factors of interest is the impact of drought between 2014 and 2018 on the profile in relation to the distance from the watercourse and climatological conditions, including its effect on the entire historical series of groundwater level monitoring.

Groundwater level monitoring at hydropedological profiles is important especially because of linking the profile to a particular watercourse and duration of the continuous monitoring. It can also be used for determination of hydraulic link between surface water and groundwater. These values would be very useful especially in determination of spread of potential groundwater pollutants via surface waters. Analyses of groundwater regime of the profile (during normal climatological and hydrological year) showed that groundwater level at all boreholes shows practically identical annual course of groundwater level in long-term, with minimum in October and maximum in April and gradual groundwater level fluctuation between these two extremes. Groundwater level at boreholes is affected by river discharges and only to a very minor extent by precipitation. Groundwater level is not very deep below the surface. The deepest levels are up to 5 m below the surface, maximum levels at boreholes, found close to rivers, rise above the terrain. Fluctuation of groundwater level is relatively large due to the overall extent of aquifer. The difference between maximum and minimum level is on average approximately 1 m. Largest differences are found at boreholes close to rivers, where they reach up to 2.5 m. Given the length of the time series one can also evaluate periods. It seems that the most important period in case of most boreholes is the 12-month period, which corresponds to seasonal refill of groundwater. In case of 70-years long series there are also statistically significant 30-year periods. The occurrence of minimum groundwater levels has a period of approximately 10 years. Groundwater level in the Thaya basin decreased by about 0.5 m after the year 1972 and also the groundwater level fluctuation is smaller due to modifications of the Thaya riverbed.

DETERMINING ACCURATE ICE COVERAGE ON DANUBE BY WEBCAMERAS

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For most Hungarian rivers, especially the Danube, the floods and other damages caused by ice have produced and are producing serious problems. Meanwhile, the number of national research on ice that improve the effectiveness of ice protection is low, and technical development is not significant at this point. The main focus of the research presented in my dissertation emphasizes the advancement of this research and to the further develop of the river ice monitoring methodology.

The key objectives are listed in the following points:

- Develop a fast, automated, cost effective, and continuous ice-collection method based on web camera images with a precision far beyond their manual or estimation procedures. Verification of the developed solution through error analysis. Solutions that do not require specialized software were preferential.
- Analyze the time pulsation and daily travel curve of the ice jam coverage ratio of the Danube with the developed high frequency measurement process.

With my paper, I would like to promote modernization of the Hungarian ice-observations and to provide a numerical basis for scientific research related to this topic.

I have demonstrated that the web-based, automated river ice-monitoring system can be used as a detailed hydrographic tool and can provide more accurate results than the currently used estimation or manual image processing methods.

I have proved that from the images of webcams to determine the rate of ice coverage, it is enough to imagine the views of the cameras in advance, with a single spatial perspective transformation, it is not necessary to use georeferencing, orthorectification, or complicated form recognition procedures for each frame. From the perspective mapping, the aspect ratio of the pixels (pixels) to the water surface in the image being examined can be calculated, and it is sufficient for the computation of ice coverage in all images with the same viewpoint. By doing this, I've narrowed the task to the grading of the water-ice pixels. A simple numerical method was developed and verified to determine the area ratio of pixels to the surface of the water. I have developed an automatic, adaptable threshold value, which distinguishes between ice and water with appropriate precision as picture points (pixels).

With my method of ice coverage determination. I observed significant temporal pulsation and daily periodicity in the ice movement of the observed Danube reach. I have found that the small number of daily estimates are not representative to determine daily average ice coverage. I recommend continuous webcams monitoring.

The new findings contribute to a more accurate understanding of the spatial and temporal structures of ice floes in rivers, as well as the methodological development of their measurability and reproducibility.

My work creates the basis for the modernization of the Hungarian ice-monitoring network. The operation of such a network provides the condition that in the future on the larger rivers ice floe forecasting and alarm systems may be established. The time series collected over the past decades provide data for national research on river ice phenomenon’s.

Keywords: fluvial ice, webcamera, ice coverage, ice observation, hyrdomethry

THE POSSIBLE WAYS OF RATIONAL USE THE KATLABUH LAKE'S WATER RESOURCES ON THE BASE OF WATER-SALT BALANCE

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In the lower reaches of the Danube on the territory of Ukraine in the Odessa region is the freshwater lake Katlabuh which belongs to the system of the Danube lakes is an adjustable water body.

During last decades, because of decrease of the area of land irrigation, volumes of water intake from the Katlabuh reservoir also significantly decreased and pumping of water from the Danube River stopped at all. All this caused deterioration of water quality. In particular, the salinity of the Katlabuh Lake in recent years exceeds by 2-2,5 times permissible rates for drinking and irrigation water.

Danube river is the main source of fresh water for the Katlabuh lake. Nowadays, the operating mode of reservoir is determined by the phases of the water regime of the river Danube:during the passage of spring high water, when the water level in the river is much higher than the water level in the lake, Danube water enters the reservoir (when it fills up to the normal back-up level); during the summer period, the floodgates are closed;in autumn, at low water levels in the Danube, floodgates are opened and there is a large discharge of water from the reservoir (to the level of the dead volume of the lake (LDV).

The purpose consists in analyzing physical and geographic, morphometric, hydrological, hydraulic characteristics of the Katlabuh lake and rivers feeding it; investigation of the water regime of the Danube River from Reni to Ishmael; calculation of water and salt balances components of the Katlabuh lake. To find ways of hydrological and ecological problems possible solution to reduce mineralization and to improve water quality.

The method of water balance is one of fundamental scientific approaches with respect to research of hydrological regime of reservoirs, lakes and ponds.Results show that precipitation on the water surface of the lake is up to 33% and supply of water from the Danube River flowing by gravity form, to a significant extent, an input portion of water balances (44%). In the output part of the water balance, evaporation from the water surface has the greatest importance (59%).During summer months the water from the Katlabuh Lake supports levels of the system of lakes Lung – Safyan. The values of discrepancies of water balances in the period of 1999-2015 fall within the limits of accuracy of the source information.

Calculation of salt balancesof lakes is carried out on the basis of water balance studies. This will allow tocheck the accuracy of calculations of the components of the water balance, and to perform mathematical modeling of the functioning of the reservoir under various conditions of its operation.
The results of calculations of the salt balance showed that the greatest part of the incoming components is given by the arrival of salts with surface runoff (40%) andthe arrival of salts with Danube water (39%). Outgoing part is determined to a greater extent by discharges of water along with salts in the Danube river (34%) and loss of salts for irrigation (31%).

Violation of the Katlabukh lake water exchange processes according to monitoring data led to the accumulation of salts and deterioration of water quality in the northern and the central parts.

When choosing a technical solution for the return of the lakes close to the natural connection with the river to improve the quality of water in the lake, it is necessary to increase the volumes of filling it with the Danube water, to increase irrigation water intakes andreduce the flow of saline waters of the rivers that feed the lake.

Keywords: Katlabuh lake**,** water quality, mineralization, water regime, balance's components.

STATE OF THE ART OF GLOBAL HYDROLOGICAL DATA ASSESSMENT WITH A FOCUS ON THE DANUBE BASIN

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Hydrological data sets, focusing on the quantitative as well as qualitative aspects of the global water cycle, are of high importance for water resources assessment and management, drought and flood protection, or disaster mitigation and should be considered as world heritage. An important aspect of global data centres is the acquisition of data, their harmonization and subsequent dissemination, taking into account various data policies. However, most of the data centres lag of a consistent documentation of in-situ observation sites (metadata and services) that would allow discoverability of stations and ultimately linking to data services. Here, we demonstrate the state-of-the art of four leading activities in the field of global hydrological data focusing on the Danube basin:

(1) The Global Runoff Data Centre (GRDC) is an international archive of river discharge time-series supporting global change research, operated by the BfG under the auspices of the World Meteorological Organization (WMO). It covers monthly discharge data from more than 9500 stations in 161 countries. GRDC was actively involved in the development and implementation of WaterML 2.0 and SOS 2.0 hydrology profile. Thus, hydrological metadata and timeseries data can now be encoded and accessed in an interoperable manner.

(2) The Global Water Quality database and information system GEMStat operates within the framework of the GEMS/Water Programme (UNEP). GEMStat hosts water quality data for rivers, lakes, reservoirs, wetlands and groundwater systems from 75 countries and approximately 4000 stations. Data is available for about 250 parameters from 1965 to 2017. For the support of interoperability the GEMStat provides ISO 19115-compliant metadata both through a catalogue user interface as well as several open web services including an OGC CSW service.

(3) The Global Precipitation Climatology Centre (GPCC) operates an archive of quality-assured monthly and daily precipitation totals based on station based in-situ measurement of rain and snowfall. A multifaceted quality control process is used, which includes harmonization of the station metadata, evaluation of redundant station reports, and quality assessment for the station reports. As a result the GPCC monthly and daily products are based on the world-wide largest quality controlled data archive comprising more than 116000 stations. The data are interpolated on global grids, and all data sets are referenced by DOIs (Digital Object Identifiers) in fully interoperable machine readable format (netCDF) through the GPCC download gateway. Through its engagement for the European Flood Awareness Centre the GPCC has intensified its activities also across the Danube catchment where some areas require substantially improved data coverage.

(4) The Global Terrestrial Network – Hydrology (GTN-H), operating under the auspices of WMO and the Global Climate Observing System GCOS, is a federated network of major global data centres, linking water-related observations with regard to climate variability and change as well as water resources assessment and management. It provides access to information and develops integrated products using data from (inter alia) runoff, lakes and reservoirs, precipitation, groundwater, soil moisture, and water quality. To address interoperability issues GTN-H supports the improvement of discoverability of stations and data of its member networks using the capabilities of the GEOSS portal by the Group on Earth Observations.

Keywords: global hydrological data, metadata and data standards, QC, harmonization, interoperability

THE DESIGN SNOW-RAIN FLOOD ESTIMATION AT UNGAUGED SITES IN THE TYSA RIVER BASIN, UKRAINE

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The extreme floods on the rivers often cause considerable and prolonged flooding of the territories, sometimes with catastrophic consequences and even with the deaths of people. In Ukraine, the Carpathians are the most dangerous flood region. On the mountain rivers of the Carpathians, which includes the basin of the Tisza River, the flow regime is characterized by the rain and snow-rain floods during the year. On the Tisza River Basin exactly in the snow-rain floods the highest discharges are observed during the year as well as for a multi-year period.

The design snow-rain flood estimation is the great practical importance, since it is the basis to plan and design of different hydraulic structures, such as dams, culverts, urban and agriculture drainage systems, etc. When designing of the hydraulic structures usually use data from hydrological and meteorological gauged stations. However, such gauged stations are very rarely located in the sites of the hydraulic structures construction. Some rivers do not have the gauging stations at all. In such cases, the estimate of design floods is carried out based on the different regionalization methods, empirical formulas, etc.

The updating of the methodical approaches and parameters of the empirical formulas which using in the determining of the design discharge of spring flood at ungauged sites of the river basin is an actual task. In this paper for the Tisza River Basin were updated the parameters of the reduction formula of streamflow which is using to calculated of the design discharge of spring flood at ungauged basin in Ukraine. The reduction formula is proposed for the using by the national normative document, which was developed in the 80's of the 20th century. The presented results illustrate that parameters of empirical formulas that were calculated according to modern observation series (since the beginning of the observations to 2015) in comparison with previously received (since the beginning of the observations to 1980) have significant changes.

Keywords: spring flood, empirical formulas, design discharge, ungauged basin, rivers-analogues

STATISTICAL ANALYSIS OF THE RUNOFF IN THE EAST MECSEK REGION (HUNGARY) IN ORDER TO UNDERSTAND CLIMATIC VARIABILITY BASED ON HYDRO-METEOROLOGICAL RECORDS

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Hydro-meteorological investigation of the small catchments of the East region of the Mecsek hills has been carried out since the 1960s. In frame of the research, daily waterlevels of the main creek of the region (Völgységi-creek) have been recorded at two gauging stations: for the upper reach in Magyaregregy settlement and for the lower reach in Bonyhád city. On the upper reach the waterlevels of one of the most important tributaries of the Völgységi-creek: Hodácsi-creek are also recorded. There are three rain gauges as well that record daily rainfall since the 1960s.

In our study we carried out statistical analyses of the 50 years long data series of the above-mentioned hydro-meteorological measurement stations, and we provide information about the changes that can be observed in the runoff characteristics of the creeks, we as well established correlations between the rainfall and the runoff characteristics and determined the extremities and the changes in their frequencies of occurence.

The above studies can help us understand the climatic changes i.e. in the temporal distribution of the rainfall and runoff and may help us develop better strategies in order to prepare for the probably more frequently occuring flash floods.

Keywords: small catchment, flash flood, statistical analysis, runoff

ASSESSMENT OF THE STATISTICAL IMPORTANCE OF THE DANUBE RIVER HISTORICAL FLOODS

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Data on historical floods along the Danube River exist from 1012 until today. In the Middle Ages floods were estimated based on historical documents, including original handwritten notes, newspaper articles, chronicles, formal letters, books, maps and photographs. From 1500 until the beginning of the organized water regime observation and measurement, floods were hydraulically reconstructed based on water marks on old buildings in the cities along the Danube (Passau, Melk, Emmersdorf an der Donau, Spilz, Schonbuhen and Bratislava).

The paper presents a procedure for assessing the statistical significance of registered historical floods using a comprehensive method of defining theoretical flood hydrographs at hydrologic stations. The applied procedure is based on the correlation analysis of two basic flood hydrograph parameters - maximum hydrograph ordinate (peak) and the flood wave volume. In order to define the probability of simultaneous occurrence of the mentioned parameters, the PROIL model was used. It defines the exceedance probability of two random variables, in the concrete case, two considered hydrograph parameters in the form:

$$P\ \{Q_{max} \geq q_{max,p}) \cap (W_{max} \geq w_{max,p})\} = P \qquad (1)$$

where:
Q_{max} - maximum hydrograph ordinate (peak)
$q_{max,p}$ - maximum discharge of the probability of occurence p
W_{max} - maximum hydrograph volume
$w_{max,p}$ - maximum flood wave volume of the probability of occurence p
P - exceedance probability.

Spatial positions of the lines of exceedance of two flood hydrograph parameters and the empirical points of the corresponding parameters of the considered historical flood in the correlation field Q_{max} - W_{max}, allow a direct consideration of the exceedance probability of the historical flood, or its statistical significance. The exposed procedure was practically applied to assess the statistical significance of the biggest registered floods along the Danube in the sector from the mouth to the dam "Djerdap 1".

At the end of the paper are given the results of the analysis of the linear trend appearance in a series of maximum annual flows at a representative hydrological station and the historical flood frequency in the considered Danube sector.

Keywords: statistical significance, flood, correlation, exceedance probability, maximum hydrograph ordinate, flood wave volume, linear trend, flood frequency

THE LONG-TERM FORECASTING OF HYDROLOGICAL CONDITION OF SMALL RIVERS AND FILLING OF THE LAKES IN DANUBE REGION DURING THE SPRING PERIOD OF YEAR

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To accomplish the task, a scientific method of long-term forecasting of spring flood on small rivers and reservoirs of the Danube region was proposed. The main problem of scientific study was the basically absent of hydrological observation network in the basins of the lakes and rivers in the whole north-western Black Sea region. Therefore, the methodological framework forecasting of the characteristics of spring floods and rain floods hardly developed. There are no recommendations how to estimate the probability of occurrence of the phenomenon in the long-term period.

The authors propose consolidation of modeling scale of the studied region and the involvement of territories with the existing hydrometeorological observation network and sufficiently studied in hydrological terms. In this case, it is expedient to involve data from long-term observations of Pivdenny Buh basin and other rivers of north-western Black Sea region.
Forecasting sequence of the spring flood layers include:

1) Typification of spring floods in accordance with their water content according to the model of discriminant function DF, which takes account of the complex of factors having an influence upon conditions of spring flood formation.

In vector-factor of discriminant function, hydrometeorological factors of the flood are included (expressed in the module coefficients):

- total water-storage in the reception basin, which take part in the spring flood formation;
- the soil moistening and frost zone;
- meteorological characteristics of the winter and simultaneity of the spring snowbreak.

2) Determination of the forecast modular coefficient of the spring flood by the regional dependence on the total moisture content of the reception basin.

3) Setting the probability of the forecasting flow layers in the long-term period.

The predicted values of spring floods are presented by map-schemes of their distribution over the territory and the probability of occurrence of the phenomenon in the long-term period, which makes it possible to estimate the scale of the spring floods, including the rivers not investigated hydrologically, which are small rivers of the Danube region.

The income of surface waters at the Danube lakes in the spring, are determined by:

a) the initial water level in the lake at the date of the forecast;

b) using the curve of the volume set the initial volume of water in the lake;

c) determining the volume of water into the lake during the period of the spring flood

g) calculating of the expected volume of water in the reservoirs for the spring flood according to the water balance equation of the lake. It is assumed that the rainfall in the water basin of the lake is compensated by evaporation with its water surface;

e) using the magnitude of the predicted volume of water in the lake during the period of spring flood on the volume curve, the maximum level of water in the lake is established, m BS.

Estimation of the filling of the lakes (million m^3) and the maximum water level (m BS) in the spring is presented as a diagram and a deviation of the allowable error.

Conclusion: For the first time, the method of the long-term forecast of surface water during the spring period for small rivers and lakes of the Danube Region was substantiated. The actual problems associated with water management of the Danube lakes for a strong and sustainable economic and social development of the Danube Region Basin were considered.

Keywords: long-term forecasting, discriminant functions, the spring flood, filling of the lakes.

DEVELOPMENT OF THE GIS-BASED KRPAN APPLICATION FOR CALCULATING EXPECTED ANNUAL FLOOD DAMAGE

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Floods are one of the most frequent natural disasters in the world. They cannot be prevented; however, their adverse consequences can be mitigated and reduced by implementing flood protection measures. An important part of an effective flood risk management is the estimation of expected damages from flood events with different return periods.

In the past, a wide variety of methodologies has been developed to assess expected flood damages. Due to their non-transferability to other areas, these methodologies are more or less different from one another and are adapted to the area for which they were originally developed. In 2014, a methodology for assessing the benefits of flood mitigation measures was prepared in Slovenia. However, the methodology needed to be reviewed and upgraded from the point of view of cultural heritage, watercourses, water infrastructure, and public infrastructure, while taking into account the latest flood damage data in past events. It was also necessary to develop an application that would allow for assessment of flood damage.

Within the project Development of a Unified Method for Assessing the Benefits of Construction and Non-Construction Measures, the method was upgraded and the KRPAN application was developed. The abbreviation KRPAN stems from Slovenian and stands for “cumulative calculation of flood damage and analyses”.

The most time-consuming part of this project was acquisition of data and the construction and optimization of relational databases. Without the relational databases, the application’s operation would be questionable, since the method for flood damage calculation is based on an extensive amount of geolocated data. The established relational database is openly accessible and can be periodically updated. Automatic updating is not yet supported. All built-in GIS tools that are essential for KRPAN’s operation are freely available (e.g., SAGA; GDAL).

We tested KRPAN for three areas in Slovenia. In addition, a test for entire Slovenian territory was carried out in order to demonstrate the validity of KRPAN’s methodology and applicability on the level of the whole country. It should be pointed out that at the state level, some entities may not contribute significantly to the final value of the expected annual flood damage, but they can contribute significantly to the value at the local level. KRPAN is primarily intended as a tool to support investment document preparation and to support decision and policy makers.

KRPAN is easy to use and user-friendly, since the calculation process consists of only two major steps: 1) definition of the calculation area, 2) run of KRPAN. However, the input data must be properly prepared to ensure the correctness of the calculation.

Keywords: flood damage, KRPAN, flood risk management, constructional and non-constructional measures, natural disasters

THE MODERN MEDIUM-SCALE MAPPING OF THE AVALANCHE DANGER IN THE UKRAINIAN CARPATHIANS

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The intensive development of information technology that is aimed at streamlining and qualitative processing of huge amounts of data has given impetus to the creation of multifunctional geographic information systems (GIS). Digital maps and electronic databases were replaced by traditional paper carriers of information, labor-intensive, routine assembly and processing. These innovations made it possible for scientists to significantly deepen knowledge in the field of avalanche.

The avalanche should be attributed to the natural components of the environment. This phenomenon is widespread and quite regular. The avalanches arise on mountain slopes and occupy a special place among the geophysical processes occurring in the hydrosphere.
Given the regularity of the occurrence of avalanches and their regularity Bozhynsky O.M. and Losev K.S. offered their definition of the concept of the avalanche danger. Under the notion of avalanche danger should be understood the naturally emerging influence of avalanches on the environment and the fundamental possibility of their impact on the population and engineering buildings.

There are various ways to classify the degree of avalanche or avalanche danger. The information about avalanches and avalanche danger constitutes a significant interest in the development of mountain areas and the exploitation of economic objects, engineering structures, communications and natural resources in the face of the risk of the threat of climbing avalanches. The process of occurrence of avalanches depends on a complex set of factors: climatic, hydrometeorological, geomorphological, geobotanical, physics-mechanical, etc.

The map presented in this work is constructed using geographic information systems (GIS) and relates to geographic. By content this map belongs to thematic maps of natural phenomena. Layer-by-layer organization of the map is applied. For its development the data from the digital model of relief (DEM) have been used. The digital model of the relief is a file of values of high-altitude marks, timed to nodes of a fairly small regular grid and organized in the form of a rectangular matrix, representing a digital expression of high-altitude characteristics of the relief on a topographic map. To construct a topographic basis, the SRTM 1 sec space data heights were used.
Not all the territory of the Ukrainian Carpathians is far from dangerous due to avalanches. So, for the occurrence of avalanches, an average maximum thickness of snow 30 cm is required on the slopes twist more than 12 degrees. Isoline 30 cm is located at the level of formation zones. Usually this is a rather low-snow and relatively low mountain belt where avalanches occur quite rarely, small in size and have a small difference in relative heights.

The mountain area is divided into four zones of avalanche danger with the corresponding background values of the average maximum snow cover height. The zone with a lack of avalanche danger is located on a relatively flat area with an average maximum height of snow cover of less than 30 cm. The average maximum height of snow cover in the zone of weak and potential avalanche danger is within 30-50 cm. The zone of moderate avalanche danger corresponds to a range of values of this characteristic 50 -70 cm zone of significant avalanche danger embraces the area where the average maximum height of snow cover is more than 70 cm. Deforestation can affect the avalanche danger of terrain and greatly worsen its safety status.

The metadata conversion algorithm is developed and the technology of thematic maps compilation using SRTM high-altitude data, aerospace images, raster and vector maps is worked out. The map is intended for scientific, geographic, recreational study of the territory.

Keywords: avalanche, avalanche danger, map, slopes, snow cower.

ESTIMATION OF THE MINIMUM MONTHLY AVERAGE RIVER DISCHARGE WITH SELECTED PROBABILITY OF OCCURRENCE AT THE POINT OF EACH EFFLUENT OR WATER ABSTRACTION FACILITY IN THE YANTRA RIVER BASIN, NORTH BULGARIA

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Yantra river basin situated in North Bulgaria, is a part of Danube river basin directorate. This investigation is performed in the framework of the project with Bulgarian Ministry of Environment and Water. From the Ministry the points for each effluent or water abstraction facility are provided. For all points it was requested to evaluate 95% probability of occurrence for minimum monthly river discharge. The provided from the project cross section (points) are along the main river body and also on the main river tributaries.

For the study data from thirteen hydrological gauging stations in the drainage basin of Yantra river are used. Time series for the 1981-2014 study period are executed. Seven homogeneous regions were determined and map with homogeneous regions for the drainage river basin is elaborated and presented. Results are discussed.

AN ESTIMATE OF 10% OF THE AVERAGE ANNUAL RIVER DISCHARGE AT THE POINT OF ANY EFFLUENT OR WATER ABSTRACTION FACILITY IN THE YANTRA RIVER BASIN.

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The study was performed for the needs of Danube river basin directorate in Bulgaria. The object of investigation is Yantra river basin situated in North Bulgaria.

From the Bulgarian Ministry of Environment and Water are provided the points for each effluent or water abstraction facility. For all points it was requested to evaluate 10% of multiannual average river discharge. For the drainage basin of Yantra river the points are 195. The selected cross section (points) are along the main river body and also on the main river tributaries. The majority of the points are located in the drainage basins of Vidima, Rositza, Belitza and Drianovska rivers.

Three homogeneous regions were determined: upper mountain tributaries; middle part of the main river body and lower part of Yantra river basin. Map with determined homogeneous regions for the drainage river basin is elaborated. The obtained results are discussed.

ASSESSMENT OF PERENNIAL FLUCTUATIONS OF AVERAGE ANNUAL WATER DISCHARGES OF THE SIVERSKYI DONETS RIVER BASIN

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The Siverskyi Donets surface water is the main source of eastern Ukraine water supply. The river basin undergoes a significant anthropogenic load, which is intensified by the effects of modern climatical changes. That is why the task of assessing hydrological regime changes of the river basins occurs.

For the research we used the observations of the average annual water discharges of the basin for the period from 1893 to 2017. The difference integral curves of variations of the average annual water discharges have been constructed for each hydrological station of the Siverskyi Donets river. By belonging to one or another part of the basin, the difference curves were divided into three groups and were constructed averaged curves for the left bank tributaries, right bank tributaries and the Siverskyi Donets river. The average annual water discharges of the considered hydrological stations had the synchronous fluctuations of the two groups: the left bank tributaries and the Siverskyi Donets river, from the beginning of the observation to the turning point in 1964 (the wet phase). From 1965 to 1976 the rivers of these two groups were in a dry phase. It changed with the rise during the time period 1977-1982, after which were observed slight fluctuations of the average annual flow of these rivers as to the norm. Just in 2006 the tendency to transition to the dry phase became clear for the left bank tributaries and the Siverskiyi Donets, At the same time right bank tributaries had asynchronous fluctuations relative to the two mentioned groups. The dry phase lasted from the beginning of observations until 1962, then (during the period 1963-1976) there were fluctuations of average annual runoff, which were close to the norm. After that, the flow of the rivers right bank was rapidly increasing (1977-2006). This situation can be explained by an increase of anthropogenic impact (increase in the volume of pumping out of mine water, the transfer of the Dnieper water through the channels of the Dnieper-Siverskyi Donets and the Siverskyi Donets-Donbas). Consequently, the reduction of production volumes and the reduction of anthropogenic load have led to the synchronization of trends in the fluctuations of water flow both left bank and right bank tributaries of the Siverskyi Donets. This trend has been since 2007.

The difference integral curves of water discharges for the rivers of the Siverskyi Donets basin have been constructed. It shows that for its left bank tributaries the dynamics of fluctuations is significantly different than the dynamics of the right bank rivers. As is known, the formation of annual water runoff is a multifactorial process under the influence of climatic, physico-geographical factors and human economic activities. The Siverskyi Donets river basin is significantly regulated, and its hydrological regime is largely influenced by the Oskil and Pecheniz'ke reservoirs. Dump of mine and industrial water and water intake for industrial and water management needs lead to changes in the hydrological regime. Significant anthropogenic load (especially on the right bank tributaries of the river) is the reason of differences in the dynamics of fluctuations of average annual runoff characteristics. During the course of the investigation were evaluated trends in the dynamics of the average annual flow of the Siverskyi Donets basin by difference integral curves during the observation period. There are certain differences in the perennial fluctuations of the average annual flow of the left bank and right bank tributaries of the Siverskyi Donets river.

The results of the research can be used to predict further changes of river basin runoff and rational use water resources in the future.

Keywords: average annual water discharge, fluctuations, dry phase, wet phase, flow

THE DIMENSIONING OF MAGYARSZÉK RESERVOIR BY MORAN'S MODEL IN ORDER TO CALCULATE THE OPTIMAL SIZE FOR POSSIBLE WATER DEMAND

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In this study we carried out hydrological calculations by the Moran's reservoir sizing method about the planned flood reducing reservoir on Baranya canal at Magyarszék. The State Organization of Water Management (the DDVIZIG) prepared the engineering plan of „The Possibilities of Constructing a Reservoir on Baranya Canal" in 2013. In this study you can also find the plan of the Magyarszék Reservoir which is meant to reduce the high water level in spring by stopping the water. The other main point of the Magyarszék Reservoir is to provide water for different purposes like irrigation during the periods of dry weather. In this study the theoretically biggest reservoir size is calculated. In case of withdrawing the largest amount of water from this reservoir the possibility of exhaustion is minimal, so the certainity of water supply is maximal. For the calculations we used the data between 2012 and 2018. The shortness of the period (7 years) made us capable of calculating the approximate optimal size of the reservoir without the help of using computer. For the precise calculations more data are needed, but this small amount of data is sufficient for the preliminary estimates and describing the calculating method.

Keywords: water storage in reservoirs, Moran's model, Markov chain, the matrix of transition probabilities, stationary limiting distribution, probability of exhaustion

EVAPORATION FROM THE WATER SURFACE IN THE TISZA RIVER BASIN ON THE TERRITORY OF UKRAINE

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Evaporation and transpiration are the main elements of the hydrological cycle. On the continents, approximately 70-75% of the total annual precipitation returns to the atmosphere by evaporation and transpiration. Evaporation from the water surface is one of the components of the water balance of the oceans, seas, lakes, bogs, reservoirs, ponds, etc. Values of evaporation from the water surface are necessary for solving practical and scientific issues related to water management, hydropower, agro-ameliorative measures, etc.

Instrumental measurements of evaporation from the surface of large water bodies are not possible at present, so direct and indirect methods are used for evaporation calculations. Direct methods consist of measuring on different types of pans and 20 m^2 tanks. Indirect methods include water-budget, energy-budget and aerodynamic method.

In the Tisza River basin on the territory of Ukraine monitoring of evaporation from the water surface was carried out at three points on the GGI-3000 pans (Table 1).

Table 1 - Points of observation for evaporation from the water surface in the basin of the Tisza River

№	Point of observation	Altitude, m	Period of observation	Number of years
1	Nyzhnii Studeyi	628.6	1962-1988	27
2	Mizhhirya	455.9	1961-2011	51
3	Berehove	112.3	1956-2015	60

As a result of the statistical processing of the data of observations in the basin of the Tisza River, the mean, maximum and minimum values of evaporation from the water surface during the season (April-November) were obtained (Table 2). The coefficients of variation of seasonal evaporation are within the range of 0.08-0.14.

Table 2 – Seasonal evaporation from the water surface in the basin of the Tisza River, mm

№	Point of observation	Mean	Cv	Maximum	Minimum
1	Nyzhnii Studeyi	375	0.12	467	284
2	Mizhhirya	428	0.08	501	365
3	Berehove	651	0.14	970	495

The dependence of the mean seasonal value of evaporation (E) on the altitude (H) was established.

$$E=726.9\ e^{-0.0011H} \quad (1)$$

The most values of evaporation from the water surface in the basin of the Tisza River are observed in July-August (Table 3).

Table 3 – Internal annual distribution of evaporation from the water surface in the basin of the Tisza River, %

IV	V	VI	VII	VIII	IX	X	XI	For a season
9	14	16	18	17	12	9	4	100

The dependencies of the monthly value dependencies of evaporation (e) on the air humidity deficit (d) for Mizhhirya (2) and Berehove (3) were established.

$$e = 13.0\ d^{0.85} \quad (2)$$
$$e = 28.9\ d^{0.56} \quad (3)$$

PEAK-FLOW FREQUENCY ESTIMATES AND REGIONALISATION FOR STREAMFLOW-GAGING STATIONS IN SLOVAKIA

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There are several distribution types used in hydrology for estimation of the distribution functions of maximum annual discharge. According to Sectorial technical standard MŽP SR OTN ŽP 3112–1:03 we use several types of theoretical distributions (Gama distribution, Log-normal distribution, Log-Pearson distribution type III., and other not excluded) for assessment of the *T*-year discharge in Slovakia. In ungauged basins with area above 20 km^2 the most frequently used method for estimation of the *100*-year maximum discharge is the method employing the exact regional dependencies of the specific yields $q_{max.100}$ on the basin area. The observed series of maximum annual discharge of 80 years duration allow us to estimate the *120*-year discharge with good reliability. The estimation of more than *200*-year discharge includes the author's experience and expertise. We have to be aware of the fact that estimation of the *1000*-year discharge is subject to high uncertainties.

In this paper the estimation of distribution functions of maximum annual discharge is based on methods described in Bulletin 17B, which was published in 1981 in USA. According to these guidelines we propose to use single type of distribution – the Pearson type III. distribution with logarithmic transformation of data (log-Pearson Type III distribution - LP3 distribution). The LP3 distribution is used for estimation of the extremes in many kinds of nature processes and belongs to the most frequently used distributions in hydrology. The LP3 distribution is very flexible, it is the generalized logarithmic-normal distribution and the Pearson distribution in the same time. The application of the single type of distribution allows estimating of *T*-year discharge also in ungauged stations just based on distribution function parameters from neighboring stations with direct measurements. The application of the single distribution type offers the regionalization using third parameter of LP3 distribution – skewness coefficient (assymetry) from neighboring stations. It is possible to find relation of the skewness coefficient to elevation of the station, basin area, forest area, or runoff depth in the station. In this paper we demonstrate the results of regionalization of the skewness coefficient in Slovak basins. Regional skewness coefficient Gr of the LP3 distribution in the Morava basin was estimated to be 0.38, while in the high mountain Belá basin it is 0.82. Application of the regional coefficient helped to improve the accuracy of the *T*-year discharge estimation, but there still remains very high uncertainty in design values assessment for the long return periods. Therefore it is necessary to include to the analysis the pre-instrumental historical floods information.

Keywords: Log-Pearson distribution Type III., regionalization, flood design values, Slovakia

MINIMAL RUNOFF OF SMALL RIVERS WITHIN SUB-BASIN LOWER DANUBE AND BLACK SEA RIVERS BASIN DISTRICT

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According to implementation of the EU Water Framework Directive the in 2016 approved Hydrografic zoning of Ukraine's territory, and the study area is divided into two areas, namely: the sub-basin of the lower Danube and the Black Sea rivers basin district. On the other hand, according to hydrological zoning, the small rivers under study flow on the territory of the insufficient moisture zone, that is, the territory within which the evaporation in conjunction with the infiltration in the average over a long period over amount of precipitation.

The main source of river feeding during the low flow period is, first of all, underground drainage, as well as precipitation that enters the channel network through its infiltration into groundwater. In winter, the regime of river runoff is determined mainly by seasonal groundwater with varying degrees of drainage of the territory, but in warm years, which began to prevail in recent decades, its share is also the thaw-rain water of winter thaw.

Investigation of the factor conditionality of the minimal runoff of the rivers of the Ukraine's insufficient moisture zone showed that the main factors for both winter and summer low flow are the geographical position of the catchments and indirect indicators of the degree of erosion of the rivers - the average height of the catchments, its area and forest area.

A distinctive feature of small rivers in the territory insufficient moisture zone the episodic or annual stop of the runoff and, as a result, it's drying (in the summer) or freezing (in winter). These rivers in the sub-basin of the lower Danube include Kogylnik, Cahul, Sarata and Chaga, and in the Black Sea rivers basin district - Great Kuyalnik, Tiligul, Chicheklya, and others. Investigations of long-term time series of winter and summer-autumn low runoff for the rivers of the studied territory indicate that there is a slight tendency to increase the runoff for the winter low runoff; for the time series of minimal runoff in warm period a clearly pronounced positive trend is observed. A significant increase in the minimum runoff is observed after the 1980s, confirming the findings of the leading Ukrainian hydrologists, regarding the impact of climate change on the water regime of the rivers during this period.

Nevertheless, the construction of the residual mass curves showed the presence of a complete cycle of water content, and hence the possibility of applying statistical methods for determining the calculated characteristics of the minimum runoff of rivers. Thus, for the rivers of the studied area, the norms of the minimum 30-day runoff (winter or summer) are defined as the average annual value of the average monthly values of the minimum runoff, as well as the duration of the periods of freezing and drying of the rivers according to the regional dependencies of the minimum 30-day (average) water flow.

The purpose of further investigation is to identify the estimated dependencies between the minimum runoff of the rivers of the studied area and climatic factors (precipitation and temperature) in order to simulate changes in the minimum runoff in the future using multimodel data of global climate modelling.

Keywords: minimal runoff, low winter flow, low summer flow, small rivers, Ukrainian Danube region.

A STUDY OF DINAMICS OF EVAPORATION FROM THE WATER SURFACE IN THE UKRAINIAN PART OF THE DANUBE RIVER BASIN

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A study of evaporation from the water surface and estimating of meteorological variables that determine its scope and dynamics have an important scientific and practical significance in terms of analysis of river runoff, including evaluation of the effect of climate variability on the hydrological regime and water resources. The connection between evaporation from the water surface and such meteorological variables as air temperature, partial pressure of water vapor, saturated vapor pressure, wind speed, water temperature has been studied by many Ukrainian and foreign researchers. In Ukraine, the last scientific summarizing of data of evaporation instrumental measurements from the water surface for purpose of analysis of the connection between evaporation and a number of meteorological parameters was carried out by A. Shereshevskyi. He used the time series of instrumental observations until 1998.

The objectives of this paper are to present results of: the study of trend of evaporation from water surface in the Ukrainian territory of the lower part of the Danube river basin during the last 20 years; the analysis of connection of evaporation with meteorological variables that are not usually taken into account, including total and lower cloudiness and solar radiation (direct radiation on horizontal surface); the clarification of connection between evaporation and air temperature, partial pressure of water vapor, saturated vapor pressure and water temperature based on the data series from 1999 (in some cases from 1995) to 2018.

The study is based on data of measurements of evaporation (according to basin evaporators) and meteorological parameters of summer months at the Bolgrad meteorological station situated in the south part of the Danube river basin. Methods of statistical analysis were used in the study. The study of evaporation dynamics revealed an increase of evaporation in summer months since 1999. The average growth of evaporation is estimated in 30%. The largest increase of evaporation in the summer period was observed in August (about 37%). As the same time, a stable reduction of evaporation in the south of Ukraine during a previous period (1960-1990) was reported in some publications.

The correlation analysis between the values of evaporation in summer months and monthly values of meteorological variables provided the following results. In summer months, the largest connection was revealed between the average monthly evaporation value and saturation deficit. The average value of the correlation coefficient for all summer months was R= 0.4 and the largest value was recorded in June (R=0.7). In case excluding the last three years from the analysis, the correlation coefficients increased to R= 0.8 and R=0.9, respectively.

However, the analysis has showed that the recent increase of evaporation can‘t be explained by changes in any meteorological variables that are usually taken into account for estimating evaporation. Therefore, the following additional meteorological values were taken for analysis: the direct solar radiation on a horizontal surface and total and lower cloudiness. The following results were obtained. The average meteorological variables coefficient between evaporation and solar radiation for all summer months was R= 0.4, the largest value was revealed for July (R=0.5). No correlation between evaporation and total and lower cloudiness was revealed (R=0.2).
As a result, it can be recommended to include the direct solar radiation on a horizontal surface in the list of meteorological variables that should be taken into account when calculating evaporation from the water surface.

Keywords: evaporation, meteorological variables, saturation deficit, correlation

MODELLING WATER QUALITY UNDER CHANGING CONDITIONS IN A NORDIC CATCHMENT

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A negative impact of multiple anthropogenic stressors on surface waters can be observed worldwide threatening fresh- and marine water ecosystem functioning, integrity and services. Water pollution may result from point or diffuse sources. An important difference between a point and a diffuse source is that a point source may be collected, treated or controlled. Agricultural activities related to crop production are considered as diffuse sources and are among the main contributors of nutrient loads to open water courses, being to a large degree responsible for the eutrophication of inland and coastal waters.

Knowledge of hydrological and biogeochemical processes are needed for climate adaptive water management as well as for introducing mitigation measures aiming to improve surface water quality. Mathematical models have the potential to estimate changes in hydrological and biogeochemical processes under changing climatic or land use conditions. These models, indeed, need careful calibration and testing before being applied in decision making.

The aim of this study was to evaluate the efficiency of various water protective adaptation strategies and mitigation measures in reducing the soil particle and nutrient losses towards surface water courses from agricultural dominated catchments. We applied the INCA-N and INCA-P models to a well-studied Norwegian watershed belonging to the Norwegian Agricultural Environmental Monitoring Program. Available measurements on water discharge, TN and TP concentration of stream water and local expert knowledge were used as reference data on land-use specific sediment, N and P losses. The calibration and the validation of both the models was successful; the Nash-Sutcliffe statistics indicated good agreement between the measured and simulated discharge and nutrient loads data. Further, we created a scenario matrix consisting of land use and soil management scenarios combined with different climate change scenarios.

Our results indicate that land use change can lead to more significant reduction in particle and nutrient losses than changes in agricultural practices. The most favourable scenario for freshwater ecosystems would be afforestation: changing half of the agricultural areas to forest would reduce sediment, total N and total P losses by approximately 44, 35 and 40%, respectively. Changes in agricultural practices could also improve the situation, especially by reducing areas with autumn tillage to a minimum.

We concluded, that the implementation of realistic land use and soil management scenarios still would not lead to satisfactory reduction in freshwater pollution. Hence, mitigation measures, enhancing water and particle retention in the landscape – as sedimentation ponds, constructed wetlands etc. – are important in facing the upcoming pressures on water quality in the future.

Keywords: water quality, INCA model, scenario analyses, climate change, mitigation measures

ALTERATION OF THE SEDIMENT BALANCE – A SIGNIFICANT WATER MANAGEMENT ISSUE IN THE DANUBE RIVER BASIN

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An increasing discrepancy between surplus and lack of sediments can be observed in many river basins. This leads to an increase of flood risks and a reduction of navigation possibilities, hydropower production and negatively impacts biodiversity. Thus, a main task is to improve sediment management as well as the river morphology. To close existing knowledge gaps quantitative sediment data have been collected all along the Danube River. A Sediment Balance was prepared, which explains the problems that arise with sediment discontinuity. The Danube River basin shows, in particular due to the disbalance of the sediment regime a heavily disturbed system. The input of suspended sediments to the Black Sea has e.g. been reduced from around 60 million tons per year to about 20 million tons per year, leading to increased coastal erosion. Moreover, long sections of the Danube River have been narrowed, channelized and disconnected from floodplains as well as morphologically degraded over the last 200 years. This has caused increased bottom shear stresses, and subsequently increases sediment transport capacities. As a consequence of both, longitudinal and lateral disturbances of the sediment supply and additional impacts of the channelization, the remaining free-flowing sections are subject to various forms of river bed degradation. Such degradation or river bed incision leads to a loss of instream structures in general, with a disappearance of gravel bars at the Upper Danube, and changes of sand bars at the Lower Danube. Possible answers to these problems are provided by a catalogue of measures.

Keywords: Sediment transport, sediment balance, Danube River, river morphology, significant water management issue (SWMI)

FUZZY LOGIC BASED FLASH FLOOD FORECAST

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The flash flood forecasting remains one of the most difficult tasks in the operative hydrology worldwide. The torrential rainfalls bring high uncertainty included in both forecasted and measured part of the input rainfall data. The hydrological models must be capable to deal with such amount of uncertainty. The artificial intelligence methods work on the principles of adaptability and could represent a proper solution. The application of different methods, approaches, hydrological models and usage of various input data is necessary.

The tool for real-time evaluation of flash flood occurrence was assembled on the bases of the fuzzy logic. The model covers whole area of the Czech Republic and the nearest surroundings. The domain is divided into 3245 small catchments of the average size of 30 km^2. Real flood episodes were used for the calibration and future oncoming flood events can be used for recalibration (principle of adaptability). The model consists of two fuzzy inference systems (FIS). The catchment predisposition for the flash flood occurrence is evaluated by the first FIS. The geomorphological characteristics and long-term meteorological statistics serve as the inputs. The second FIS evaluates real-time data. The inputs are: The predisposition for flash flood occurrence (gained from the first FIS), the rainfall intensity, the rainfall duration and the antecedent precipitation index. The meteorological radar measurement and the precipitation nowcasting serve as the data source. Various precipitation nowcasting methods are considered. The risk of flash flood occurrence is evaluated for each small catchment every 5 or 10 minutes (time step depends on precipitation nowcasting method).

The Fuzzy Flash Flood model is implemented in the Czech Hydrometeorological Institute (CHMI) – Brno Regional Office. The results are available for all forecasters at CHMI via web application for testing. The huge uncertainty inherent in the flash flood forecasting causes that fuzzy model outputs based on different nowcasting methods could vary significantly. The storms development is very dynamic and hydrological forecast could change a lot every 5 minutes. That is why the fuzzy model estimates are intended to be used by experts only.

The Fuzzy Flash Flood model is an alternative tool for flash flood forecasting. It can provide first hints of danger of flash flood occurrence within the whole territory of the Czech Republic. Its main advantage is very fast calculation and possibility of variant approach using various precipitation nowcasting inputs. However, the system produces large number of false alarms, therefore the long-term testing in operation is necessary and the warning releasing rules must be set.

Keywords: Fuzzy Logic, Flash Flood, Operative Hydrology.

APPLICATION OF RAINFALL-RUNOFF MODEL: CLIMATE CHANGE IMPACTS ON RESERVOIR INFLOW

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The impacts of climate change are beginning to be felt in the Czech Republic. In recent years, we were challenging a dry period, which threatens to continue affecting Czech economy, agriculture and personal comfort of local people. The need to adapt to climate change is obvious. The groundwater resources are in continuous decline, so the surface water supplies are increasing in importance. How would the quantity of available water change in the future? How much water would we be able to store within the year to manage it during the dry seasons?

Rainfall-runoff models enable us to simulate future changes in hydrological conditions based on climate projections. On of such tools is Runoff Prophet, the conceptual lumped model being developed at the Institute of Landscape Water Management at Brno University of Technology. It is used to simulate time series of monthly river flow in a catchment outlet without the need to describe the morphological characteristics of the catchment. Runoff Prophet produced good results of calibration and proved its suitability for conceptual hydrological modelling in variable hydrological conditions of the Czech Republic.

The aim of the paper was to assess the possible impact of climate change on future inflow into Vír I. Reservoir, one of drinking water resources for Brno, city of 380 000 inhabitants. Recently developed software Runoff Prophet was used to simulate future river flow time series. The model was calibrated on the catchment of gauging station Dalečín on Svratka River as the reservoir inflow. Prognosis of future river flow were performed using climate scenarios prepared by Global Change Research Institute of Czech Academy of Sciences. These scenarios (RCP types) are based on outcomes from different regional climate models of Euro-CORDEX initiative. Characteristics of possible future air temperature and precipitation in the basin were evaluated in terms of its impact on reservoir management. The results of hydrological modelling gave the perspective of expected changes in Vír I. inflow yield. The options of using Vír I. Reservoir as a drinking water supply for Brno in coming decades were assessed.

Keywords: Runoff Prophet, climate change, rainfall-runoff model, hydrology, water resources

PROJECTION OF LITHUANIAN RIVER RUNOFF AND WATER TEMPERATURE

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The Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report announced that in many regions changing precipitation and temperature are altering hydrological regime and affecting quantity and quality of water resources. In the last time the representative concentration pathways (RCPs) scenarios are used in scientific literature for both climate projections and modelling of potential future changes in the river hydrological regime. There is a lack of scientific studies of climate change impact on the thermal and hydrological regime of Lithuanian rivers according to RCP scenarios. Therefore, the aim of this study is to project the future changes of runoff and water temperature in the 21st century according to four RCPs. Six Lithuanian river catchments from three different hydrological regions were selected for this study. Using HBV software, the generated hydrological models were used for calculation of runoff projections according to climate scenario output data (temperature and amount of precipitation). Scenario output data are acquired from three global climate models (GFDL-CM3, HadGEM2-ES and NorESM1-M) and four RCP scenarios (RCP2.6, RCP4.5, RCP6.0 and RCP8.5). River temperature projections were made using projected air temperatures and the relations based on the observed average monthly river water and air temperatures.

At the 21st century the following changes of scenario output data are projected: an increase of air temperature and positive or negative alterations of the precipitation amount depending on the projection method. These results indicated a decrease of spring flood discharges in both periods (2016-2035 and 2081-2100) of the projections; in some rivers flooding events are expected to diminish substantially, especially under the high warming scenario RCP8.5. Spring flood peaks tended to take place at earlier dates due to an increased air temperature in winter and subsequent replacement of snow precipitation by rainfall. River water temperature is expected to increase as a consequence of projected higher air temperatures in the entire Lithuanian territory. According to the RCP8.5 scenario, the majority of the studied rivers will warm up by more than 5 °C at the end of the 21st century.

Keywords: climate scenarios, HBV software, projections, runoff, water temperature

APPLICATION OF THE "CLIMATE-RUNOFF" MODEL TO THE ASSESSMENT OF THE DUNABE RIVER BASIN WATER RESOURCES IN THE XXI CENTURY ACCORDING TO THE CLIMATE SCENARIOS (A1B)

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Changes in the water resources of the Danube River in conditions of global warming determine the strategy of water management in the southwestern part of Ukraine in the XXI century. Water resources of the catchment can be estimated due to the average long-term annual runoff at the mouth of the river. Forecast of possible changes in water resources in the future according to climate scenarios is provided by calculation using mathematical models. In this paper, the authors used the "climate-runoff" model developed in the Odessa State Environmental University. The "climate-runoff" model consists of two blocks. The first unit performs assessment of natural water resources according to meteorological data, the second block takes into account the impact of water management activities. The theoretical basis for calculating of natural runoff using meteorological data is a mathematical model of water-thermal balance. Determination of annual runoff in the conditions of water management transformations is based on the generalized results of imitation stochastic modeling using equations of water management balances. The model was calibrated and verified on materials of the river runoff of different geographical zones of Ukraine. It was used to identify water resources for both small and large rivers of Ukraine (Dnieper, Southern Bug, Dniester, Danube). Natural runoff, calculated on meteorological data, is called "climatic" and is identified with zonal runoff. The model is sensitive to modern changes in climatic factors and allows to assess with satisfactory accuracy the zonal runoff and the influence of the underlying surface, including water management transformations. Calculations are performed according to meteorological stations (precipitation, air temperature, air humidity deficits). The calculation results are generalized in the form isolines map of average long-term annual runoff for the certain period. The accuracy of the determination of the statistical parameters of the natural annual runoff using the "climate-runoff" model is within the permissible limits and for the average long-term annual runoff this value is ±10,0%. If the input data into the model is the data from the climate change scenarios, the model can evaluate the water resources of the future. In our studies, the input data was taken from the database of the international project ENSEMBLES. The scenario A1B (model REMO) was chosen for calculations as being characterized by the highest correspondence of observed and simulated meteorological series in the retrospective period. In the catchment area of the Danube River, 32 point-nodes of coordinate grid of scenario data with a step of 25 km were considered. All of them are located in different physical and geographical zones. The total annual runoff from the of the Danube River catchment area was calculated as average weighted value whith using zonal areas. the values of runoff in areas by parts. It was found that the water resources of the river in the XXI century will decrease very gradually: in the period 1990-2030 - by 6,1% (the changes will not be statistically significant), in the period 2031-2070 - by 17,9 %, during the period of 2071-2100 the reduction of water resources will reach 22,0%. This result is due to the high wateriness of the Danube mountain areas, located in the west and northwest of the catchment. In these mountainous areas the effects of warming manifest weakly both through the manifestation of vertical zoning, and through the melting of glaciers. Thus, in the XXI century, changes in the water resources of the Danube will not be destructive and irreversible.

Keywords: water resources, climate change scenarios, the model "climate-runoff"', forecast of Danube water resources change

MODEL OF FORMATION MAXIMAL RUNOFF ON THE SMALL RIVER IN THE UKRAINIAN PART OF DANUBE BASIN

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In accordance with the provisions and objectives of the EU Floods Directive (2007/60/EU) for the floods of rare probability of occurrence (once in 100, 50 or 200 years) need to perform: preliminary flood risk assessment (Article 4,5); the preparation of maps and flood risk threats (Article 6), and the approval of the flood risk management plans (Article 7).

Figure 1. Ukrainian part of Danube basin

In order to implement the Flood Directive for reduce the risk of flooding and flood mitigation along floodplain areas, a model of forming the maximum runoff of OSENU can be used, which is developed and implemented using the example of the small rivers in the lower part of the Danube, as well as for the rivers of Transcarpathia (Ukrainian part of the Tisza River Basin), Figure1.

The authors proposed the variant of calculation scheme, realizing principal two operators' model of runoff formation. It is obvious that two operators must describe the process of formation of channel runoff: "precipitations – slope influx" and "slope influx – channel runoff". Just such shall be the theoretical and methodical base of problem solving, concerned, for example, with forecasting of hydrographs of channel runoff under atmospheric precipitates. However in practice of hydrological calculations, on solving of a whole series of problems, the great interest is given not to the whole hydrograph of channel runoff, but to its maximum ordinate, moreover, to infrequent exceedance probability. Model that is offered enables to enter «climatic amendments» directly to maximal snow supply and runoff forming precipitations during spring floods, and also to the runoff coefficient.

The model of formation of the maximum river flow, proposed OSENU allows quantifying estimate:

- The influence of factors of the underlying surface (forested, swamps, mountain areas);
- The various types of transformation of slope and streamflow runoff. In particular, the method allows us to estimate the degree of influence of the floodplain on the value of maximum discharge during high floods;
- The model that is offered enables to enter «climatic amendments» directly to maximal snow supply and runoff forming precipitations during spring floods, and also to the runoff coefficient.

For mapping floodplains along the Danube in the Ukrainian part of the basin, it is possible to show the flooding zones during the passage of floods rare repeatability using OSENU techniques to determine the maximum flow of ungauged rivers.

The model has been tested on many years for the rivers of Ukraine and neighboring countries, it has no restrictions in terms of the origin of floods and catchment areas. With a minimum of input data (morphometric characteristics of catchment) model can be used to ungauge basins in order to obtain the maximum value of expenses given exceedance probability and simulation of possible changes in context of climate change for flood risk management.

Keywords: maximal runoff, Ukrainian Danube Region, small river, flood.

HIGH-RESOLUTION SOIL MOISTURE MODELLING OVER AUSTRIA

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The main aim of this study is to investigate the value of ASCAT satellite soil moisture data for regional soil moisture modelling over Austria. Soil moisture modelling is performed by using conceptual hydrologic model (TUWmodel) which is calibrated and validated in 213 catchments in the period 2005-2015. Two variants of calibration are tested. In the first, hydrologic model is calibrated to runoff only and daily ASCAT soil moisture data are used for comparison between modelled and satellite soil moisture estimates. In the second, multiple objective calibration by using both runoff and ASCAT data is performed. Both approaches are compared and validated by using data from the calibration (2005-2015) and validation period 2015-2018. The results are discussed in terms of runoff model efficiency and temporal correlation of soil moisture.

Keywords: soil moisture, ASCAT, TUWmodel, Austria

CALIBRATION OF HYDROLOGICAL MODELS BY PEST MODEL

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Hydrological phenomena take place in the hydrological system, which is governed by nature, and are essentially stochastic. These phenomena are unique, non-recurring, and changeable across space and time. They are simulated through various hydrological models that seek to integrate complex processes, as demonstrated by continuous functions. This procedure is hindered by the lack of data and simplifications used to solve the mathematical model. These limitations are responsible for the errors or deviations in calculation results given by the model and measurements in the field. When calibrating the model we are trying to determine the coefficients appearing in individual functions, so that the differences between the calculations and measurements are kept at a minimum. Since any river basin with its own natural characteristics and any hydrological event therein, is unique, this complex process is not researched well enough.

Most software for using hydrological models is equipped with algorithms for automatic determination of the optimum set of parameters. These algorithms do not take into account the natural characteristics of the hydrological system that is non-linear, so the forecasting results of such a model are not well enough.

The question is how to find proper solution for inverse nonlinear equations. Using the appropriate expert knowledge and information, the parameters are pondered, and the pattern of optimum model parameters is formed. Thus, we directly, and proportionally to the expert knowledge, affect the outcome of the inversion procedure and achieve better results than if the procedure had been left to the selected optimization algorithm that include regionalization and different kind of transformations included in the software package PEST.

PEST is the life work of John Doherty, and more than a software it is a “continuous creation”, where passion, precision, innovation, genius and creativity converge. It is not an exaggeration to define PEST the most incredible and inspiring Masterpiece in model calibration and uncertainty analysis presently available for any kind of modelling.

Using PEST for hydrologic model calibration Nash-Sutcliffe efficiency easily reach 0,95 or more.

OVERLOOK ON THE DANUBE RIVER BASIN HYDROLOGICAL FORECAST (DAREFFORT PROJECT)

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Flood forecasting and hydrological measurements in the Danube river basin have a long-standing tradition. Early measurements date back to the 18th century; by the end of the 19th century public services for systematic measurements of water levels were introduced in most countries. Flood forecasting services have been established since the mid-20th century. In the late 20th century and early 21st century, IT and the overall digitisation accelerated flood forecasting development all over the world. The development of forecasting services and professional progress can be followed through scientific and professional meetings that have been held biennially since 1961. In 2019, the meeting will take place in Kiev.

Organisation and operation of services differ according to development and forecasting needs in individual countries. It is important to distinguish between forecasts for smaller rivers in the river basins and those for the main Danube river flow. The water causing floods in the middle and low part of the Danube river had been in river channels before for more than a week. Flow forecasting Organisation and operation of services differ according to development and forecasting needs in individual countries. It is important to distinguish between forecasts for smaller rivers in the river basins and those for the main Danube river flow. The water causing floods in the middle and low part of the Danube river had been in river channels before for more than a week. Flow forecasting is then more or less based on hydraulic calculations and simple empirical equations. A river's torrential character is much more evident in its headwater part, where flows are subject to precipitation and snowmelt. The hydrological forecasting in these areas is related to measurements and rainfall forecasts, and although progress has been noticed, hydrological forecasts show a relatively low confidence level in this part of the Danube basin. The reason for the large variations between the forecasts and the measured flows is in the highly unreliably meteorological forecasts and the lack of data on snow cover.

The development of services for discharge forecasting is closely related to users' needs. Flow forecasting for the main Danube river flow is subject to navigation needs, as international agreements and protocols on navigation have caused its intensive development after World War II. The Danube is an internationally navigable waterway; navigation largely depends on hydrological conditions, as during low or extremely low water levels river transport stops for security reasons. The Danube hydrological regime is characterised by ice that forms in slow-flowing water. Occasionally the entire water surface freezes and the ice builds up, forming an ice dam (i.e. ice jam) which then causes damming and so-called ice floods.

Hydropower producers are another important user of the forecasts. Hydropower plant output levels depend on water availability. On the other hand hydropower plants, with their own reservoirs and power generation needs, change the water regime and affect the reliability of hydrological forecasts. Depending on the needs, forecasting services are differently organised in each country. In some countries, along with Slovenia, services work closely together under one organisation, at the same location. Elsewhere, particularly in larger countries, the meteorological service and the hydrological service are separate and possibly even under the jurisdiction of different ministries. For example, in Germany the meteorological service is under federal government's jurisdiction, while hydrological services are separately organised in each land or their regions. Lately the work of hydrological forecasting services has been supported by the Copernicus European Flood Awareness System (EFAS) at the EU level, developed at the Joint Research Centre (JRC). Systematic monitoring of quality and forecasting reliability is presently only carried out by JRC and individual services.

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THE POTENTIAL OF PREDICTING LOW FLOW PERIODS FOR THE CENTRAL EUROPEAN RIVERS WITH A SPECIAL FOCUS ON SUMMER 2018

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During the last decades several low flow periods, at European level, occurred with severe impacts not only on the river itself but also on the civil society. Low flow periods affect navigation, hydropower production and the environment. A hot, dry 2018 summer has left the central European rivers and lakes at record low water levels, causing chaos for the inland shipping industry, environmental damage and billions of euros (dollars) in losses. Similar to floods, low flows are natural events which can considerably restrict different uses and functions of the river and impact water quality and the aquatic ecosystem. Moreover, it is expected that climate change will to lead to drier summers in Western Europe and therefore possibly to more frequent and more severe low flows in rivers in the future. The results presented here show that the summer 2018 low flow situation, over the Danube, Rhine and Elbe rivers, could have been predicted one season ahead using previous months sea surface temperature, sea level pressure, precipitation, mean air temperature and soil moisture. Moreover, the statistical model was able to predict more than 85% of the water levels for August 2018 on month ahead. The lagged relationship between the monthly and/or seasonal streamflow and the climatic and/or oceanic variables vary between 1 month (e.g. local precipitation, temperature and soil moisture) up to 6 months (e.g. sea surface temperature). Given that all predictors used in the model are available at the end of each month, the forecast scheme can be used to predict extreme events and to provide early warnings for upcoming low flow periods.

DERIVING A NEW RATING CURVE AT RĂDĂUȚI-PRUT GAUGE STATION ON PRUT RIVER BASED ON COUPLED HYDRAULIC SIMULATIONS AND FLOOD ATTENUATION IN STÂNCA-COSTEŞTI RESERVOIR

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Prut River, which represents the border between Ukraine and Romania on about 42 km, and the border between Romania and the Republic of Moldova on about 742 km, is the last important tributary of Lower Danube River. The dam Stânca-Costeşti on Prut River is operated in common by the water authorities of Romania and the Republic of Moldova. The reservoir behind the dam has a volume of 1.4 x 10^9 m^3 and a length of about 100 km. The input in the reservoir is controlled by Rădăuți-Prut gauge station in Romania and Şirouți gauge station in the Republic of Moldova.

Two important floods took place on Prut River in 2008 and 2010 respectively. The flood in 2008 was characterized by a maximum discharge of 4240 m^3/s and a volume of 1.5 x 10^9 m^3, while the flood in 2010, which was multi-modal, has a maximum discharge of 2300 m^3/s and a volume of 2.65 x 10^9 m^3.
A hydraulic model between Rădăuți-Prut gauge station and the downstream section of Stânca-Costeşti dam was developed in order to obtain the best operation rules during flood period. In the calibration phase of the hydraulic model, considering the floods in 2008 and 2010, it was found out that the actual rating curve at Rădăuți-Prut gauge station over-evaluates the flood volume. Thus, the flood volume at Rădăuți-Prut gauge station was 230 x 10^6 m^3 larger than the flood volume downstream the dam and the volume accumulated in the reservoir. A similar situation occurred for the flood in 2010.

It was clear that the upstream boundary condition (the discharge hydrograph) in the hydraulic model should consider the real discharges, meaning that a modified rating curve had to be derived.

A large number of simulations were undertaken in order to reproduce the water level variation in the reservoir and the released discharges downstream the dam based on the computed input in the reservoir and the operation rules during the flood period. In a first stage, the simulations were run in steady state considering a range of discharges between 0-4500 m^3/s. The computed discharges based on these rating curves did not lead to a good agreement between the measured water levels in the reservoir and the computed ones. In a later stage, unsteady simulations based on the measured water levels at the gauge station as upstream boundary condition were undertaken.

After deriving the roughness coefficients of the hydraulic model, all the floods for a period of 30 years were recalculated based on the registered water levels at the Rădăuți-Prut gauge station and the non-steady rating curves. Finally, these floods were statistically processed, computing the maximum discharges and the flood volumes corresponding to different probabilities of exceedance. The design flood was used then to derive the best operation rules of the reservoir during current, medium and exceptional floods.

HYDROLOGICAL DROUGHT AND FIRE RELATIONSHIP

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Drought can be defined in meteorological terms or in relative terms with respect to hydrology and ecosystems. Meteorological drought is not a necessary or a sufficient condition for fire, because fires burn during conditions of normal seasonal aridity (e.g., dry summers that occur annually or early autumn). Drought occurs without wildfires in the absence of ignitions. However, when drought occurs, both live and dead fuels can dry out and become more flammable. Hydrologic drought as natural event is the result of long-lasting rainfall in the catchment area leading to the gradual depletion of water resources in the river network and the occurrence of a drought. Typically, hydrological drought is recorded as a river runoff below acceptable critical value.

Summarized that means – methodological drought is not enough to reproduce the fire phenomenon (we can have methodological drought in winter time but not fire phenomenon). Hydrological drought predestines with a very big probability the real wildfires. The reason for that is a very low level of groundwater, lack of moisture in the ecosystem (including plants) leads to natural or anthropogenic easy ignitions and fires.

There are different approaches to drought classification targeting different purposes (or different impacts) that have led to creation of different drought indices. In general, three sets of drought indices can be distinguished by the three types drought: meteorological drought, soil moisture drought and hydrological drought. More than 100 drought indices have been developed to investigate the drought and its impact.

The authors explore the relationship between hydrological drought and forest fires. They present projections of fire-related drought indicators: the hydrologic indicator 7Q10 (the lowest 7-day average flow that occurs on average once every 10 years).
Although drought does not cause direct fire, it provides favorable conditions for the ignition and distribution of forest fires. The implementation of the hydrological drought as an approach for fire risk assessment has just started in Bulgaria. For this purpose, the assessment of the feasibility of using the hydrological 7Q10 drought index as a fire hazard indicator in real time is based on archive information on the variation of hydrological characteristics in the river network before and during an actual fire in an accepted pilot catchment.

The Hydrologic Index 7Q10 for the pilot catchment of the Struma River was determined according to the rules for the last 15 years (2003-2017) using the daily water flows from all hydrometric stations. The specified index 7Q10 is considered to be the minimum flow runoff value in the rivers below which fire conditions are generated.

The results of the presented study confirm the possibility of using the hydrological 7Q10 drought index to assess the risk of real-time fires by information on runoff from operational hydrological stations. One of the largest fires in the Struma River in 2017 occurred in an area identified as a fire on a highly hazard area according to the hydrological drought index 7Q10.

Keywords: hydrology, drought, fires, indexes

DEVELOPMENT OF STREAMFLOW DROUGHT INDICES IN THE MORAVA RIVER BASIN

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The territory of Czechia currently suffers from a long-lasting drought period which has been a subject of many studies, including the hydrological ones. Previous works indicated that the basin of the Morava River, a left-hand tributary of the Danube, is very prone to the occurrence of dry spells. It also applies to the development of various hydrological time series that often show decreases in the amount of available water. The purpose of this contribution is to extend the results of studies performed earlier and, using the most updated daily time series of discharge, to look at the situation of the so-called streamflow drought within the basin. 46 water-gauging stations representing the rivers of diverse catchment size were selected where no or a very weak anthropogenic influences are expected and the stability and sensitivity of profiles allow for the proper measurement of low flows. The selected series had to cover the most current period 1981–2018 but they could be much longer, which was considered beneficial for the next determination of the development direction. Various series of drought indices were derived from the original discharge series. Specifically, 7-, 15- and 30-day low flows together with deficit volumes and their durations were tested for trends using the modifications of the Mann–Kendall test that account for short-term and long-term persistence. In order to better reflect the drivers of streamflow drought, the indices were considered for summer and winter seasons separately as well. The places with the situation critical to the future water resources management were highlighted where substantial changes in river regime occur probably due to climate factors. Finally, the current drought episode that started in 2014 was put into a wider context, making use of the information obtained by the analyses.

Keywords: climate change, nonstationarity, stochastic processes, statistical hydrology, Moravia

TIME SERIES ANALYSIS AND FORECAST ESTIMATES OF THE MEAN ANNUAL WATER RUNOFF OF RIVERS IN OF THE PRUT AND SIRET BASINS (WITHIN UKRAINE)

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Knowledge of the cyclicity features in the fluctuations of river runoff, duration and character of the change of the periods of the wet years and dry years in river basins, and especially their prediction provides invaluable assistance in the planning and sound management of the water resources, improving the operational efficiency of the hydropower, reclamation and other water facilities.

The main aims of study are calculations of hydropower potential of small mountain and foothill rivers in Prut and Siret river basin (within the Ukraine) in wet years and dry years phases. Based on the identified patterns in stochastic fluctuations in multi-annual mean of river runoff, according to observation data, were found theirs forecast estimations for the near future are found.

The systematization, generalization, estimation of the variability of time series of the mean annual water runoff of rivers in of the Prut and Siret basins has been carried out, and its cyclic structure has been revealed.

Applied are methods of mathematical statistics random variable and random functions, stochastic variable, probability theory.

Fluctuations of mean annual runoff water of rivers are treated as a random process with discrete time t □ T (random sequence). In particular, the value t = 1, 2...N can be attributed to the available number of observations for N years; values t = N+1, N+2... refer to the following periods of time, and the value t = N-1, N-2...- to the previous periods. In order to describe the process fluctuations of mean annual runoff water used the whole range of functions, the most important of which are: the function of mathematical expectation; dispersion function or standard deviation; probability distribution function; autocorrelation function. Also have been involved different statistical criteria (uniform distribution, series, the longest series), integral residual mass curves etc.

The greatest success in the study of temporal runoff fluctuations achieved if one considers the long time series of hydrological characteristics in large scale, i.e. the water runoff of large basins, which are not significantly affected by the random factors and local conditions. In order to establish the patterns of fluctuations in the runoff of the rivers of the Prut and Siret basins, and taking into account the above circumstances, the study was based on the data of the mean annual runoff water of the Prut river in Chernivtsi during the period of observation in 1895-2015. Used were observational data of the mean annual runoff for the period 1882-2015 and the adjacent basin of the Dniester River near the city of Zalishchiki.

The regularities found in the structure of the time series of the mean annual water runoff of the rivers in the Prut and Siret basins can be qualified as cyclical. In addition to cycles, are highlighted the periodic phases of the wet years and dry years in river basins.

Until 2020-21 the of dry years phase will continue, and then the of wet years phase with duration of 16-17 years can be expected and from 2037-38 the of dry years phase will again continue until 2048-49.

Keywords: rivers of Prut and Siret basin (within the Ukraine); mean annual runoff; multi-annual variability, cyclicity in the fluctuations runoff.

ASSESSMENT HARMONIZATION PROBLEMS OF THE LONG RETURN PERIOD FLOODS ON THE DANUBE RIVER

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One of the basic problems of the flood hydrology was (and still is) the solution of the relationship between peak discharges of the flood waves and probability of their return period. Importance of extrapolation derived from these variables (so called frequency curve) is especially necessary for proposal of water management and flood control plans. Directive 2007/60/ EC of the European Parliament of 23 October 2007 concerning the assessment and management of flood risks requires member States to draw up flood hazard maps of floods with very long return periods *T* (*500* to *1000* years). All methods of estimating floods with a very long return period are associated with great uncertainties. Determining of the specific value of a *500*- or *1000*-year flood for engineering practice is extremely complex. Nowadays hydrologists are required to determine not only the specific design value of the flood, but it is also necessary to specify confidence intervals in which the flow of a given *100*-, *500*-, or *1000*-year flood may occur with probability, for example, 90%. The assessment of the design values along the Danube channel is more complicated due to application of different estimation methods of design values in particular countries downstream the Danube. Therefore it is necessary to commence the harmonization of the flood design values assessment methods.

In order to refine the design values of the floods, it is also necessary to use information on the occurrence of historical floods. We therefore firstly analyzed the occurrence of historic floods in the Danube River basin. Then we have proposed regionalization method of determining a parameter of skewness of the log Pearson type III distribution function. In this study, the measured time series of the maximum annual discharge *Qmax* from selected gauges of the Danube Basin were used for the estimation of the coefficients of the theoretical distribution functions. For the estimation of the distribution function we used only one distribution - the Pearson Type III distribution with logarithmic transformation of the data (log Pearson Type III distribution - LP3 distribution). To estimate regional skew coefficient for the Danube River we use 20 *Qmax* measured time series from water gauges along the Danube River from Germany to Ukraine.

Keywords: harmonization, floods, design values, Danube River, LP3 distribution

VISUAL INSPECTION FOR DEFINING SAFETY UPGRADING STRATEGIES FOR SCHOOL BUILDINGS- VISUS

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Ensuring the safety of people in case of natural hazards is one of the main concerns of public administrators in hazard-prone territories, particularly with reference to strategic and relevant major public buildings, such as schools. This requires the definition of a rational and effective strategy for risk reduction, based on the knowledge of: the level of risk, type and gravity of criticalities, possible countermeasures, and relative costs.

SPRINT Laboratory of the University of Udine (I) developed a specific methodology, named VISUS (Visual Inspection for the definition of Safety Upgrading Strategies) that is specifically conceived for facing the above highlighted problems. VISUS provides an integrated framework to support the planning and the decision making of future actions in the field of safety. In particular, the methodology allows making a sort of technical triage, based on visual inspections, the results of which could directly used for defining comprehensive safety upgrading strategies for school facilities.

VISUS has been recently adopted by UNESCO and positively tested in prototypal projects within of the Comprehensive School Safety (CSS) framework. Meeting of UNESCO-VISUS Experts (MUVEx) under umbrella of UNESCO Section on Earth Science and Geo-Hazards Risk Reduction establish the network. The task of the network is to ensure the implementation of the methodology in the field of protection of school buildings against natural disasters including water related hazard. The VISUS methodology helps decision-makers at line ministries of education, national disaster management bodies and other relevant institutions to learn about the risks of school facilities and how to find economically optimal solutions for their higher level of security.

ESTIMATION OF THE FLOOD MAXIMUM VOLUMES FOR VARIOUS DURATIONS OF THE RIVER RUNOFF AND THEIR MUTUAL DEPENDANCES: A CASE STUDY ON HRON RIVER IN SLOVAKIA

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In applied hydrology, it is problematic to assign the flood wave volume values with a certain probability of exceedance to given corresponding T-year discharges. This dependence is highly irregular, and requires to know the flood wave course of the given probability exceedance. For this reason, this work deals with the determination of the annual maximum discharge volumes on the Hron River for the time duration of t = 2-, 5-, 10-, and 20-days (V_{tmax}). The series of 84 years (1931–2015) mean daily discharges of the Hron River at Banská Bystrica station was used as input data to calculate the maximum annual volumes of runoff of the Hron River. Subsequently, the theoretical curves of exceedance of the maximal discharge volumes V_{tmax} were determined by the Log-Pearson distribution of the Type III. This type of probability distribution is used to estimate maximum (extreme) values across a range of natural processes. The results of the estimated T-year volumes by using PL III distribution were compared to other types of theoretical distribution functions used in hydrological extreme analyses in Slovakia (Gamma, Log-normal, etc.). The second part of our work was focused on the bivariate modelling of the relationship between T-year maximum volumes with different duration and peak discharges. In the case of modelling without evaluating this mutual dependence of the flood wave characteristics, they may be overestimated (in the case of the negative dependence) or underestimated (in the case of the positive dependence). The Archimedean class of copula functions was used as mathematical tool for the dependence modelling. The three usually most used types of this class of copulas in hydrology (Clayton, Gumbel-Hougaard and Frank) were selected. The LP III distribution was used as marginal probability distribution function. Subsequently joint and conditional return periods of the T-year maximum annual flows and T-year maximum volumes with different time duration were calculated. The first one defines joint return periods as: the return periods using one random variable equaling or exceeding a certain magnitude and/or using another random variable equaling or exceeding another certain magnitude. The second one is conditional return periods for one random variable, given that another random variable equals or exceeds a specific magnitude.

Keywords: Hron River, maximum runoff volume, peak discharge, probability distribution, T-year volume, copula function.

GENERAL FEATURES OF THE FORMATION MAXIMUM FLOW IN THE PRIPYAT RIVER SUB-BASIN

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Investigation of the maximum flow carried out in the practical use of its design characteristics in the operation of hydraulic structures for the regulation of wastewater, the implementation of measures on human settlements, industrial and agricultural objects. The calculation of the unfavorable task of modern hydrology is to ensure changes in the hydrological regime in the respective regions of Ukraine. The study of the characteristics of maximum runoff is devoted to a number of works by scientists-hydrologists of the Ukrainian Hydrometeorological Institute, Taras Shevchenko National University of Kyiv and the Odessa State Environmental University.

The volumes of maximum runoff, the period of passage of the largest water consumption and the time of fixing the highest levels on the right bank tributaries of the Pripyat River within the territory of Ukraine vary within a fairly wide range. This heterogeneity is the result of the complex interaction of a number of physical and geographical factors, as well as various hydrological and morphometric characteristics of rivers in the studied region.

On the rivers of the Pripyat sub-basin, the maximum runoff is formed either during the melting of snow or from the precipitation of heavy rains. A characteristic phase of the hydrological regime of the rivers is the spring flood, which is formed annually in the spring, as a result of snowmaking and rain falling in this case.

Another significant hydrological phenomenon that characterizes the maximum runoff is rain flood. Almost annually on the rivers of the Pripyat there are several rain floods, which cause significant elevations of water levels above the boundary markings. There are also autumn and winter growth levels, the first caused by rains, the second - thaws. As a result of rain falls, they often lead to damage to engineering structures, flooding of settlements, industrial sites and agricultural land.

The purpose of the study is to synthesize the initial information on water flow, processing and analysis of the characteristics of spring flood (runoff volume, maximum runoff, duration of run and onset times) and rain flood, in particular the warm period, according to the data of 28 hydrological stations within the studied region. To achieve the goal, statistical, cartographic using the GIS software and complex methods were used.

In the course of performing the relevant calculations it was possible to determine the proportion of water and flood from the average long-term runoff volume, compare the value of time costs, to build histograms and schedules of their duration, as well as periods of onset.

The results of the study revealed the dominant role of spring flood in forming the maximum runoff over floods, but one can not deny that the volumes of spring flood in the basin of the right bank of the Pripyat have undergone some changes in the time section. The decrease in the share of spring runoff from the annual volume in the Pripyat sub-basin can be explained by the intra-annual redistribution of runoff observed recently on rivers throughout the territory of Ukraine.

Keywords: runoff volume, maximum runoff, spring flood, share of spring flood from annual runoff volume, hydrological regime.

MAXIMUM RIVERS RUNOFF IN THE BASIN OF TYSA AND PRUT WITHIN UKRAINE

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The rivers Tysa and Prut belong to the Danube basin and within the boundaries of Ukraine originate in the mountains of the Carpathians. Rain and snow-rain floods are typical for rivers in their basins. Often those floods acquire the character of dangerous phenomena with devastating consequences. The characteristic of such an extreme hydrological phenomenon is the maximum runoff of rivers, which serves as a measure of danger for the population and the economy. It has usually expressed as the largest discharge, volume or depth of runoff for the flood wave this year. The maximum discharge can be the largest mean daily discharge, the largest in the observation term (taken in one of the term of the daily measurement periods) or instantaneous (absolute daily maximum).

Aim of the research is to estimate the maximum runoff of rivers in the basins of Tysa and Prut and its multi-annual variability. A base of average annual and maximum discharges - largest daily mean values and the largest in the observation term, with 36 gauging stations on the rivers from the beginning of observations to 2015, have been created. At 8% of the gauging stations, the observation period is ≥ 70 years, 81% - 50-70 years, so 89% of gauging stations have periods of observation ≥ 50 years, and only 11% - ≤ 50 years.

In current research were used methods of mathematical statistics processing of random variables and random functions, as well as statistical analysis of relations between hydrological variables. Practical value is determined by the further development of studies of maximum runoff of the rivers of the Carpathian Mountains and their generalization according to modern observation data.

Explored basins within Ukraine locate on different slopes of the Carpathian Mountains: rivers of Tysa basin - on the southwest slopes, rivers of Prut basin- on the northeastern slopes. This causes certain features of physical and geographical factors in the formation of highs on the rivers in the basins of Tysa and Prut. Ranges of catchment basins of investigated rivers are in the Tysa basin F=25,4-9140 km ^{2}, in the Prut basin - F=18,1-6890 km ^{2}. The average maximum runoff of rivers in the observation term in the multi-annual period varies– 17,1-1873 $m^3 \cdot s^{-1}$ in the Tysa basin, and 15,7-1133 $m^3 \cdot s^{-1}$ in the Prut basin. Accordingly, maximum specific discharges runoff are 90,6-1886 and 71,8-867 $dm^3 \cdot s^{-1} \cdot km^{-2}$. Absolutes instantaneous of the maximum runoff during observation in the Tysa basin recorded on the river Turia - Turia Polyana (F = 98,6 km^2) - 6298 $dm^3 \cdot s^{-1} \cdot km^{-2}$, in the Prut basin on the river Kamianka - Dora (F = 18,1 km^2) - 4790 $dm^3 \cdot s^{-1} \cdot km^{-2}$. The coefficients of variation in the Tysa basin are smaller (0,37-0,89) than in the Prut basin (0,54-1,1). Asymmetry coefficients have positive values that vary in wide range from 0,2 to 5,5.

On small rivers, there are significant differences between the maximum daily average values and peak highs values, but with increasing river length, those differences are less. Comparative analysis of maximum and average annual runoff of water in discharges has shown that first one is on 9-16 times bigger than average.

Integral curves of differences, autocorrelation and spectral functions were used to study the multi-annual variability of the maximum runoff of rivers. Their analysis showed that cyclic components are present (5-7, 12-15 years), in the modern period there is a tendency to decrease the maximum. If the connection between the average annual discharges of the Tysa and Prut rivers is rather tight (the correlation coefficient is 0.81), then it is absent for the highs due to the difference in the orography, climatic conditions, and, as a matter of fact, the genesis of floods.

Keywords: basin of the rivers Tysa and Prut, maximum runoff of the rivers, multi-annual variability, statistical parameters and distribution functions.

THE WMO PROJECT ON CATALOGING HAZARDOUS HYDROMETEOROLOGICAL EVENTS: LESSONS LEARNED BY UKRAINE

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In the successful implementation of the UN Disaster Risk Reduction Program one of key places belongs to the national hydrometeorological services, whose information, forecasts and warnings are an important segment of the Disaster Early Warning System. The 17th World Meteorological Congress (2015) adopted the resolution that provided for a work on developing identifiers for cataloging hazardous hydrometeorological events to standardize a description (cataloging) of events and to establish their linkage with disasters which they cause. The experts team of the World Meteorological Organization developed the Guide on cataloging hazardous hydrometeorological events. 17th session of the WMO European Regional Association (2018) decided to implement the WMO Project to test this Guide. In July 2018 experts from 13 European countries, including Ukraine, met in the office of the German Weather Service to consider and adopt organization and methodological issues of the Project implementation.

The purpose of this paper is to present Ukrainian lessons and experience learned from participation in the WMO Project with the emphasis on issues of its implementation in Ukraine. The methodology of the Project implementation was based on the following principles: each country used its own methods and rules of recording and warning hazardous hydrometeorological events; it is not foreseen to combine events into groups by their type (meteorological, hydrological, climatic, etc.); a description of events is in a line with the Common Alerting Protocol-SAR2.0 to avoid duplication and incorrect interpretation. Cataloging hazardous hydrometeorological events was carried out by the experts team, which included representatives from the Ukrainian Hydrometeorological Institute and the Ukrainian Hydrometeorological Center, on the basis of concerted procedure of identification and registration of hazardous hydrometeorological phenomena according to the adopted classification as "the dangerous level" (orange color) and "the very dangerous level" (red color).

When a formation of hazardous hydrometeorological events with negative consequences was expected experts have begun to fill out the corresponding table in EXCEL format. This table included the fallowing information: the universal 32-digit unique identifier as a mean of fixing events (determined by using the software placed on the site www.uuidgenerator.net); date and time of creation of forecast/warning about hazardous events; expected time of events beginning/ending; the events type (primary and/or system); the administrative region(s) of events observation; the event headline; the events description; the linkage with other hydrometeorological events; the events status (ended or continuing); post processing information (description of damages and measures undertook to minimize they). The filled table was sent to the European Regional Climate Centre, which is operated at the German Weather Service. This Centre was designated as the responsible organization for methodological and technical coordination of the Project implementation, including the integration of information gathered from countries, the consolidation information into the Regional Database, and the unification of several events into one regional event.

The participation in the WMO Project allowed to assess the present state of work in the Hydrometeorological Service of Ukraine on standardizing (cataloging) information about natural disasters caused by hazardous hydrometeorological events. A number of issues were identified. These issues can be divided into two large groups: organizational and methodological ones. The paper addresses these issues and provides conclusions and recommendations for improving this direction of work in the Hydrometeorological Service of Ukraine.

Key words: hazardous hydrometeorological events, cataloging, WMO Project, lessons

SYNOPTIC CONDITIONS FOR DROUGHT AND DRY WINDS IN UKRAINE DURING AUGUST, 2010 (CASE STUDY)

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Droughts and dry winds that often accompany them are among the most high-impact hazards observed over the growing season in Ukraine. Although drought and dry wind phenomena belong to different spatial and temporal scales, under certain circulation conditions they may appear simultaneously, mutually reinforcing the negative impact on various sectors of the economy, especially agriculture. The circulation conditions in the atmosphere, which observed during the summer months of 2010 over Eastern Europe, are a prime example of synoptic processes that lead to formation and stability of a complex of dryness phenomena. The aim of the study is to detail a structure of the regional atmospheric circulation and to define the typical synoptic processes, which led to formation drought and dry winds in Ukraine during August, 2010.

As the initial data the daily observations at 24 meteorological stations for period from July, 31 to August, 31, 2010 were used for detect the dry wind phenomenon. In Ukraine dry wind (or 'sukhovey') is fixed as simultaneous combinations at least in one term of observations such meteorological values as: air temperature is 25 °C and higher, wind speed at 10 m height is 5 m/s and more, and the relative air humidity is 30% or lower. Drought intensity was estimated using the standardized precipitation-evapotranspiration index (SPEI). Synoptic processes including blocking conditions were analyzed using pressure fields (at sea surface and the pressure levels) from NCEP/NCAR reanalysis. As an indicator of state of the zonal flow related to blocking processes proposed European Continental Blocking Index (ECBI) was used. For localization of place the onset of air masses, in which the dry winds are formed, the backward trajectories of air particles were constructed using NOAA HYSPLIT model for period of 120 hours at three levels: sea surface, 1500 m and 3000 m.

During the summer months of 2010 weak and moderate drought was observed in all agroclimatic areas of Ukraine. Dry conditions especially forced in August, 2010, what coincided with spread of dry winds in different parts of Ukraine. The longest multi-days dry wind was observed in Mariupol' from July, 31 to August, 20. Long dry wind periods were observed also in Kropyvnytsky (12 days), Kharkov (9 days) and Simferopol' (8 days). Dry winds had the greatest distribution in period of 5-6 August 2010, when they observed at 11 stations simultaneously.

The significant spread of dry winds over the territory of Ukraine in first half of August, 2010 occurred under formation over Europe meridional type of atmospheric circulation with the development of a blocking process. Analysis of index ECBI showed that during period from July, 30 to August, 18 it had positive values (from 0.23 to 0.66), which indicates the presence of a blocking process in the region. Analysis of backward trajectories showed that during the blocking episode over Eastern Europe, at the Ukrainian stations, where dry winds were observed air masses came from regions of northwestern Kazakhstan, the Ural Mountains and the east and northeast of European Russia. The repeated increasing the number of dry winds in period from August, 23 to August, 27 occurred under the establishment over Ukraine a low-gradient anticyclonic field, which promoted intensive air heating on this area. At the same time ECBI had negative values (from - 0.16 to - 0.38) that correspond to the absence of blocking process.

The study showed that appearance of dry winds is easy under the backdrop of drought, in case if conditions for wind increasing are created, usually on the peripheral parts of anticyclones. This is a sufficient condition, because the necessary conditions for high temperature and dry air are already provided by a drought, which developed under previous blocking process in the atmosphere.

Keywords: drought, dry wind, atmospheric circulation, blocking process.

EXTREME LOW-WATER AND THE DANUBE NAVIGATION IN 2018

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Low-water is one of characteristic phases of the hydrological mode of the Danube river. In separate years in summer and autumn in the river basin during a great while anticyclone weather sets in and low-water on the Danube gains character of the extreme hydrological phenomenon as critical shoal. In the XXI century such a situation was marked in 2003, 2011 and 2015 practically along the whole length of the navigable Danube. In 2018 duration of extremely subzero charges and water levels periods on the Danube appeared to be the most. At the beginning of July the critical shoal phase coming resulted in considerable limitations in navigation under navigational conditions. It foremost affected navigation on the Upper and Middle Danube, where the maximal passing draft appeared below a 2,0 m. In this situation pilotage expectation time increased considerably, and also the long periods of the complete stopping of navigation appeared. As a result, the volume of goods shipping grew short more than twice. Thus, the basic problem preventing to the Danube transportations market growing is found to be in critical parts of water-ways, which parameters presently fall short of to the requirements produced to the internal water-ways of international value. One of the real ways of solving the problem can be creating continuous cascade of propping up areas by constructing the hydro-stations on the upper Danube.

Keywords: low-water, the Danube river, critical shoal, navigation, water-way

DANUBE FLOODPLAIN PROJECT

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In compliance with the EU Water Framework Directive (WFD), the 2nd Danube River Basin Management Plan puts forward ambitious targets for floodplain restoration, recognizing the multiple benefits of such restoration measures for flood risk management, nutrient retention, water quality, biodiversity and ecosystem services. At the same time, the implementation of the EU Floods Directive (FD) requires the identification of key areas for intervention in the scope of the 1st Flood Risk Management Plans 2015. The challenge is to implement/develop solutions to ensure the sustainable, long-term use of water resources in the Danube region and in the same time to reduce the adverse consequences of floods.

The project shall support joint and integrated approaches within the Danube Basin District and the implementation of win-win solutions for both directives (WFD and FD) in order to improve transnational water management and flood risk prevention contributing to the sustainable provision of ecosystem services.

The project will offer:

1) feasibility studies for priority areas on the Danube River (upstream, middle and downstream) and on the selected major tributaries including Cost Benefit Analysis (CBA) and assessment of ecosystem services benefits (application of ESS methodology and tools) and
2) Danube River Basin Guidance for floodplain conservation, restoration and land management.

The aim of the project is to achieve long-term solutions through restoration and conservation of floodplains with the effect to lower the flood risk (discharge peaks) of the Danube and the selected tributaries/areas. The planned outputs are useful to the River Competent Authorities located within the Danube River Basin District.

The benefit of the project is a step forward to real implementation of the measures, namely, the feasibility studies. The project will thereby contribute to the successful implementation of the 2nd and 3rd Danube River Basin District Management Plans and the 1st and 2nd FRMP (both from 2015 / 2021) which are expected to contribute to the ambitious restoration targets of the first PoM and RBMP. Thus the Danube Basin countries under the umbrella of the ICPDR will upgrade their capacities for this task, especially as all parties are key partners of the Project. With the restoration and conservation of floodplains, the Project will also contribute to achieve the 15% restoration target of the EU 2020 Biodiversity Strategy.

The innovative character is given by the common agreed criteria (Multi Criteria Analysis) at Danube wide level, taken into account improving simultaneously flood risk management and restoring floodplain ecology (considering the requirements of WFD, FD, Birds and Habitats Directive, Biodiversity Strategy).

The public/stakeholders consultation and participation is involved in the selection of the pilot areas and associated measures.

Keywords: Danube River, management plans, flood risk protection, floodplain restoration, win-win situation

STEPS TO IMPLEMENT OF DIRECTIVE 2007/60/EC IN UKRAINE AND PRELIMINARY FLOOD RISK ASSESSMENT

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Steps to Implement Directive 2007/60/EC in Ukraine is part of a global reform of the implementation of integrated water resource management based on the basin principle. Implementation of the Directive 2007/60/EC in Ukraine was established by the resolution of the Cabinet of Ministers of Ukraine dated October 25, 2017, No. 1106 "On the implementation of the Association Agreement between the European Union and the European Atomic Energy Community and their member states, of the one part, and Ukraine, of the other part". Three Steps to Implement the 2007/60/EC In Ukraine are envisaged. The first step is to improve Ukraine's legislation about flood risk assessment and management. The second step is the preliminary flood risk assessment of the territories of nine river basin districts of Ukraine. The third step is to establish flood risk management plans of areas of the river basin districts of Ukraine. Flood risk management plans are establish once every 6 years based on flood hazard maps and flood risk maps. Flood risk management plans are approved by the Cabinet of Ministers of Ukraine.

As of 2019, in accordance with the Action Plan for the implementation of the Association Agreement between the European Union and the European Atomic Energy Community and their member states, of the one part, and Ukraine, of the other part, Ukraine has made changes to its own legislation in the field of flood risk assessment and management. Developed a methodology for preliminary flood risks assessment, a methodology for developing of flood hazard maps and flood risk maps, Procedure for developing flood risk management plans was approved also. Preliminary flood risk assessment was completed in 2018, the results of which were submitted to the Cabinet of Ministers of Ukraine.

Preliminary flood risk assessment provided an analysis of historical river flooding and past river flooding that caused of adverse consequences, especially for human health and life, the environment, cultural heritage, economic activity and infrastructure. In Ukraine identified 899 emergency events or signs of emergency situations (object, local, regional and state levels) associated with pluvial flood. The probability of exceeding of maximum water levels for three scenarios (0.2%, 1.0%, 10.0%) are estimated, according to 196 hydrological stations. Based on combinations level of emergencies with pluvial flood and the probability of exceeding of maximum water levels were identified of potential flood risk and areas of potential significant flood risk (APSFR). In Ukraine 221 APSFR were identified, with a total length of 8748 km. From the 221 APSFR, 17 have transboundary status. With very high flood risk 233 settlements, from which 175 settlements are located in the Dniester river basin district (RBD). The Dniester RBD has the more APSFR - 86 APSFR with a length of 2903 km.
Now, Ukraine is on the third stage of the implement Directive 2007/60/EC. By 2020 flood hazard maps and flood risk maps of areas of river basin districts of Ukraine should be developed. These maps will begin the process of developing flood risk management plans in 2021, which will be approved in October 2022. After that, Ukraine will begin the second six-year cycle of developing flood risk management plans.

HYDROLOGY AND LIMNOLOGY - KEY TOOLS IN RIVER BASIN MANAGEMENT

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Established in 1956 to foster transboundary limnological research in the Danube River Basin, IAD bridges basic and applied science and contributes to conservation of aquatic biodiversity and river basin management in the Danube Region. Major achievements encompass research of floodplain ecology, inventories of macrophytes and invasive alien species, and sturgeon protection – all components of ecosystem service, conservation and restoration. As aquatic ecosystems depend on water quantity, hydrology has a key role (also shown in the IAD monograph of the Danube, 1967): discharge and flow are basic elements of river ecosystems, influencing directly aquatic organisms, sediment transport and morphology and, hence, the habitats of aquatic biota. In 2004, IAD organized an UNESCO IHP workshop to highlight the importance of cooperation between limnology and hydrology in river basin management.

Several examples and case studies of the Danube River Basin (DRB) illustrate this cooperation:
(1) Over the past 30 years, *water quality* improved and *nutrient load* of the Danube into the Black Sea decreased. While limnologists provide concentration, hydrologists measure discharge. Around 2000, IAD provided the first water quality maps of the DRB, based on saprobiology.
(2)
Flood control is of great importance for human society in view of potential damage. Hydrological modeling and forecast are important tools to manage floods. Former natural water retention areas were lost through river channelization, leading to a loss of biodiversity and ecosystem services. Floodplain restoration works need expertise from both hydrologists and limnologists to understand local dynamic processes shaping the morphology and regaining ecological connectivity. Some organisms need the dynamic change of discharge to survive, while the near natural hydromorphological structures provide habitats to aquatic and semi-terrestrial species to complete their life cycles. This is exemplified e.g. in the restored floodplains near Neuburg, Bavaria, and downstream of Vienna.

(3) A *sediment balance* for the DRB is presently elaborated by hydrologists. Sediment erosion, accumulation and transportation, addressing longitudinal connectivity, are significant water management issues, affecting both aquatic habitats and biota. Sediment retention by hydropower dams affects river morphology and organisms. Again, abiotic and biotic features complement each other in the riverine ecosystem.

(4) *Ecological flow* is an essential element for aquatic organisms. It is altered by hydropower dams (e.g. residual flow) and by navigation (e.g. submerged constructions, groynes). IAD biologists investigate the behavior of benthos and (migratory) fish, while hydrologists provide models of various scales to predict flow and discharge under different scenarios.

(5) *Climate change* is a new threat for the biota not only because of increased water temperatures, but also because of altered precipitation and discharge. A Swiss hydrologist assessed the impact of melting Alpine glaciers on the Danube River discharge and calculated a share of up to 9% at the beginning of the delta, some 2500 rkm downstream of the source. Limnologists have to consider such changes in assessing and predicting the impact on aquatic life.

Keywords: aquatic ecosystems, nutrient load, biodiversity, hydromorphology, modeling

ANALYSIS OF LOW-FLOW CONDITIONS IN A HETEROGENEOUS KARST CATCHMENT AS A BASIS FOR FUTURE PLANNING OF WATER RESOURCE MANAGEMENT

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Understanding and prediction of low-flow conditions are fundamental for efficient water resources planning and management as well as for identification of water-related environmental problems. This is problematic especially in view of water use in economic sectors such as tourism where water-use peaks usually coincide with low-flow conditions in the summer time. In our study, we evaluated various low-flow characteristics at 11 water stations in the non-homogenous Ljubljanica river catchment in Slovenia. Approximately 90% of the catchment is covered by karst with a diverse subsurface, consisting of numerous karst caves. The streams in the remaining part of the catchment have mainly torrential characteristics.

Based on daily discharge data we calculated and analysed values of low-flow statistics, such as the baseflow index, the mean annual minimum n-day flow, low-flow percentiles from flow duration curves, and the mean flow. Seasonality of low flows was identified and analysed based on seasonality histograms, seasonality indices, and seasonality ratios. In addition, by analysing hydrograph recession curves, recession constants were determined to assess the catchment's responsiveness to the absence of precipitation. By using different calculation criteria (different methods, segment lengths, and periods for calculating the initial discharge) we analysed the influence of individual criteria on the values of low-flow recession constants. Recession curves are widely used in different fields of hydrology, for example in hydrological models, baseflow studies, for low-flow forecasting, in assessing groundwater storages which are crucial in view of assessing water availability for planning water resources management (e.g. for water use management in tourism).

Moreover, in the study we also investigated the possible impact of projected climate change (scenario RCP4.5) on low-flow conditions in two sub-catchments of the Ljubljanica river catchment. For the evaluation we used the lumped conceptual hydrological model, where rainfall and evapotranspiration are the required data. For periods 2011-2040, 2041-2070, and 2071-2100 low-flow conditions were evaluated based on various low-flow statistics and seasonality indices and compared with the 1981-2010 period. The lowest discharges at all water stations in the Ljubljanica river catchment occur mostly during the summer months. Our results for the future show that during the period of the lowest flows, these could be even lower. However, the uncertainty/variability of the results is very high and as such should be taken into account when interpreting and using the results.

The study demonstrates that evaluation of several low-flow characteristics is needed for a comprehensive and holistic overview of low-flow dynamics. In non-homogeneous catchments with a high karstic influence, the hydrogeological conditions of rivers should also be taken into account in order to adequately interpret the results of low-flow analyses. This proved to be important even in case of neighbouring water stations.

Keywords: low-flow analysis, low-flow indices, Ljubljanica River catchment, climate change, heterogeneous karst catchment

LOWLAND RUNOFF SURVEY AND MODELING FOR DECISION SUPPORT IN MANAGEMENT OF THE TRANSBOUNDARY PALIC-LUDAS CATCHMENT AREA

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Palic and the Ludas lakes are located in the northern part of Vojvodina, Serbia near the town of Subotica, just a few kilometers south of the Hungarian border. While Palic lake has a long history as a touristic attraction and a nice recreational setting, Ludas lake and the surrounding steppe plains are habitats of international importance and protected by the Ramsar convention on wetlands. The lakes are connected through the Palic-Ludas canal. Thus Ludas lake is fed partially from Palic lake, but also supplied by the Körös river. The majority of the catchment area of the Körös river is in Hungary, this way the water supply problems related to the lakes are transboundary. The lake system is also drained by the Körös, which finally enters the Tisza river.

Water quality problems and water quantity decrease are both identified and are escalating threatening factors at the lake system in the past decades. Several studies have been carried out in the past about the possible reasons and solutions. The authors have studied the previously published results and have been participating in a cross-border co-operation project funded by the IPA, in frame of which a comprehensive survey and measurement program has been carried out in order to develop, among others, a rainfall-runoff model of the catchment for the investigation of water supply scenarios of the lake system in order to substantiate a monitoring network and program for the sustainable management of the lakes.

In our presentation we introduce the area, the problem, the field surveying and measurement methodologies and results, the modeling process and the model itself, concluding transboundary responsibility for water supply to the lake system, with a possible complex connection to one of Hungary's major water management issues.

Keywords: transboundary catchment, field surveying, lowland runoff modeling, water resources management

WATER RESOURCES OF THE LOWER DANUBE RIVER AND THEIR USE WITHIN THE TERRITORY OF UKRAINE

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The main hydrological characteristics of the Lower Danube River are presented: its water runoff and sediment yield. The catchment area, belonging to the Lower Danube River of Ukraine, was determined on the basis of the SRTM. It is equal to 6454 km^2. The catchment area of the largest rivers, flowing into the lakes of the Lower Danube River, was specified. The largest of them is the Yalpukh River, with a catchment area of 3280 km^2. The features of the hydrochemical regime of local rivers were also investigated.

On the basis of remote sensing data, the water areas of the four largest lakes, located in this territory, was determined. Their water area at normal water level is as follows: Kahul – 90.6, Yalpukh-Kugurluy – 235, Katlabukh – 60.7, Kytai – 52.9 km^2. This water area is approximately 10% smaller than project data.

Using the data of standard monitoring and remote sensing data, the ecological state of the lakes was studied. The largest water mineralization, reaching 5 g/dm^3, is observed in Lake Kytai, the smallest value (about 1 g/dm^3) is registered in Lake Kahul. The worst water quality is observed in the northern part of Lake Kytai, where the water mineralization, concentration of nutrients, biochemical oxygen demand are the largest.

Based on remote sensing data, the features of water temperature in lakes were studied. It was found that the water temperature is very variable. In different conditions the highest temperature can be observed in different lakes. To some extent it depends on weather conditions and algal bloom. In some cases the highest water temperature was observed in Lake Kytai, despite its northernmost location.

The spatial and temporal features of algal bloom were described. The largest algal bloom is characteristic for the Lake Katlabukh and for the southern part of Lake Kytai. In the course of the year, the largest algal bloom is usually observed in August in sunny and warm weather.

Data on water use in the Lower Danube River basin are presented. The largest volume of water is used for irrigation, much less – for the industrial and drinking water supplying. The irrigation area and its changes over the past decade were specified. The loss of water for the evapotranspiration from the irrigated area was calculated as well. The need for irrigation water was determined.

The prospect of water use in the Lower Danube River basin within the territory of Ukraine was assessed.

Keywords: water resources, Lower Danube River, lakes, ecological state, remote sensing

ELECTRONIC ATLAS "ACTUAL AND FORECASTED CHANGES OF THE CLIMATE SYSTEM IN UKRAINE"

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The developing of strategies and plans for adaptation to climate change requires scientifically sound information about actual and expected climate change and their impacts, identifying risks and vulnerabilities to climate change at the level of regions, districts, territorial communities or economic sectors. Due to it, it is necessary to have a comprehensive description of the state, actual and forecasted climate change in the regions of Ukraine. To this aim has developed an electronic atlas "Actual and forecasted climate change in Ukraine", which allows to provide the necessary information in a visual and systematic form.

The electronic Atlas provides in format on climatic and agroclimatic indicators: state, the rate of change and its statistical significance in current climatic period (1981-2010), projections of their change and its significance to the middle of the 21st century, expected average long-term values in 2021-2050 for the A1B scenario. Information is available in graphical and tabular form for all regions of Ukraine and the country as a whole. Assessment of indicators variability is realized according to daily data of Ukrainian hydrometeorological network (187 stations) for 1981-2010.Projections of change in average long-term values of on climatic and agroclimatic indicators in 2021-2050 relative to 1981-2010 are calculated according to the daily data of regional climate model REMO / ESNAM5 obtained in the European project ENSEMBLES FP-6 with a resolution of 25 km.

The electronic atlas contains sets of maps and tables, grouped into two thematic sections: "Climatic conditions" and "Agroclimatic conditions of crops cultivation". The first section holds subsections with information on quantitative characteristics of thermal, humidity and wind regimes, and specialized climatic indices used in various sectors of the economy. The second presents information about favorability of agroclimatic conditions for cultivation of the main field crops (winter wheat, spring barley, maize) in Ukraine according to the degree of their moisture and heat supply in different periods of vegetation cycles. Their change in the current climatic period, possible changes and expected values by the middle of the XXI century for all regions of Ukraine. The evaluation of adverse phenomena for crop yield formation was performed based on the hydrometeorological block of the “Weather-Harvest” model of UHMI.

Database management tools are integrated into the atlas to edit its content and control data availability. The help section contains information about the levels of statistical significance used to evaluate the significance of rate of change, the rules for reading maps to correctly understand the information displayed on them etc.

Electronic atlas "Actual and forecasted changes of the climate system in Ukraine" has applied nature, contains information that can be used in assessing the vulnerability of regions, districts, sectors of economic on climate change. The findings will be widely used in developing strategies and plans for climate change adaptation both individual regions and industries.

Keywords: climate change, electronic atlas, temperature rise, agroclimatic conditions, climate projections

SPATIAL-TEMPORAL PRECIPITATION CHANGE IN UKRAINE

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Significant role in weather and climate shaping plays atmospheric moisture and water cycle. It affects all components of the climate system, including the hydrosphere, forming their main features and characteristics in different regions. Precipitation is an important characteristic of moisture that is the main source of water reserves renovation. The general conception about moisture change in Ukraine gives analysis of time series of spatial distribution of average annual and seasonal values of precipitation and relative humidity, frequency and intensity of extreme rainfall, number of days with rain or without rain, maximum duration of wet (with precipitation) or dry (non-precipitation) periods.

The researches were conducted according to daily data of hydrometeorological observation network of Ukraine (187 points) in the current climatic period 1981-2010.It is established that the intensity of precipitation in Ukraine in the current climatic period, unlike the temperature change, is very heterogeneous both in the territory and during the year. Annual precipitation in Ukraine is *likely* to have increased. The most intensive changes are observed in the western Forest-Steppe, except the Sumy region where it is *likely* to have decreased. Precipitation is *very likely* to have increased in the autumn and *likely* – in spring. Change of precipitation on winter is 4%/10 years and it is about *as likely as not*, and on summer its likelihood is *unlikely.*

Unlike amount of precipitation, with a probability of 95% or more can be argued that the number of days with rain decreased significantly across most of the country. The intensity of change is increasing from west to south and southeast. Instead, the number of days without rain and the maximum duration of dry period is *virtually certain* to increase throughout the country. These changes are exacerbated in the southeastern and southeastern directions and in the steppe and eastern forest-steppe they are 11-16 days/10 years. A rapidly growing number of days without rain is in Polissia, Ivano-Frankivsk and Lviv regions. Also, noted a tendency to increase in maximum duration of the dry period. A significant increase in the duration of dry period, accompanied by a significant increase in temperature, especially its maximum values, caused an increase in aridity. It is *likely* that the number of arid days in Ukraine increases by an average of 2-3 days over 10 years. On the Steppe and eastern Forest-Steppe-aridity is growing most intensively. There is a dangerous tendency to increase the frequency of arid conditions in the area of sufficient atmospheric humidity, which covers the Polissia and northern regions of the Forest-Steppe.

Increasing amount of precipitation and a significant decrease in days with rain indicate an increase in their intensity. This conclusion is confirmed by extreme rainfall data: maximum precipitation per day, precipitation per day greater than 15 and 50 mm. It is established that the number of days with extreme precipitation is *likely* and *very likely* to increase, although the change in the maximum daily average precipitation is insignificant and very heterogeneous in the territory both in direction and in values.

Found that in the current climatic period in Ukraine changes not only the amount of precipitation but also the humidity. *Very likely* that average annual, spring and summer relative humidity decreases, in winter it *likely* increases and does not significantly change in autumn. The decrease in the average relative humidity for the year is observed almost all over the country and is most intense in the eastern Forest-Steppe and northern Steppes. Changes in precipitation, increase in their frequency and intensity, especially in the warm period, are caused by the increase in the intensity of convection, the power of the precipitation processes and the change in atmospheric circulation.

Keywords: climate change, precipitation change, aridity, extreme rainfall, non-precipitation period

DATABASE OF RIVER WATER BODIES HYDROMORPHOLOGICAL MONITORING

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Monitoring of hydromorphological parameters is a part of the program of state water monitoring in Ukraine in accordance with the Decree of the Cabinet of Ministers of Ukraine No. 758 (19/09/2018). Hydromorphological assessment is important for determining the ecological status of water bodies. According to the Decree the hydromorphological monitoring has started in 2019.

The basis for the hydromorphological monitoring is the survey unit, by which the hydromorphological status of water bodies is determined. The data of the hydromorphological assessment will be uploaded to online database providing authorized access via Internet. Users can enter, process, and store information; download the final results of the assessment and comparing them. The database will contain information concerning all of the water bodies within the river basin districts of Ukraine including survey units assessed. The database will allows uploading additional photos, maps and satellite images.

Results of hydromorphological monitoring will be set out in two data entry forms for each survey unit, specifically: the site protocol and the protocoll of hydromorphological assessment. Protocols are based on the European Standards EN 14614:2004 (CEN, 2004), EN 15843:2010 (CEN, 2010) and a on the method developed and tested in Slovak Republic (SMHI, 2004).

The site protocol contains the general descriptions of the survey unit. The site protocol consists of five separate parts: Unit's general information, Unit's channel parameters, Riparian zone and floodplain characteristics, Catchment attributes, Hydrological conditions. The protocol of hydromorphological assessment includes the actual assessment and is divided into 10 categories and 16 parameters (Table 1).

Table 1. List of parameters included in the assessment of the hydromorphological quality of water bodies in Ukraine

Category	Parameters
1 Channel geometry	1a Planform
	1b Channel section
2 Substrates	2a Extent of artificial material
	2b "Natural" substrate mix or character altered
3 Channel vegetation and organic debris	3a Aquatic vegetation
	3b Extent of woody debris
4 Erosion/deposition character	4a Presence of in-channel
5 Flow	5a Impacts of artificial in-channel structures
	5b Effects of catchment-wide modifications to natural flow character
	5c Effects of daily flow alteration
6 Longitudinal continuity	6a Artificial structures
7 Bank structure and modifications	7a Extent of unit affected by artificial bank material
8 Vegetation type/structure	8a Land cover in riparian zone
9 Adjacent land-use	9a Land cover beyond the riparian zone
10 Channel-floodplain interactions	10a Flooding of floodplain
	10b Degree of lateral movement of river channel

The final score will be reported in five hydromorphological quality classes: from the class 1 (near natural) up to class 5 (severely modified).

Keywords: river water body, database, hydromorphological assessment, survey unit

EVALUATION OF THE IMPACT OF LAND USE AND CLIMATE CHANGE ON THE NITRATE LOAD OF A SMALL CATCHMENT USING HYDROLOGICAL MODELS

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The nitrification of surface waters and ground waters is one of today's most important water quality problems. In Hungary, we expect to see an elevation in temperature and an increase in the frequency of extreme water balance situations in the future, that can affect both the hydrological system and water quality. Therefore, when designing appropriate water protection measures, it is essential to take into account the potential impacts of predicted climate change and alterations in land use, and also to quantify them. The objective of our study is to estimate the nitrate load and its seasonal fluctuation of a Hungarian small catchment by combining hydrology and water quality models. Our other objective is to quantify possible changes in surface water nitrate load with different climate and land use scenarios and also to evaluate the impact of certain measures to reduce nitrate leaching.

For our research, we coupled the runoff model PERSiST and the water quality model INCA-N to model hydrology processes and nitrate transport. The study area is the sub-catchment of Tetves Creek, which belongs to the catchment area of Lake Balaton. The modelling covers two periods: the current situation is represented by the period from 2006 to 2015, while expected future changes are examined for a mid-21st century period. The meteorological data required for the model simulations were obtained from FORESEE database. The setup and calibration of the models was performed in several steps in accordance with the relevant literature, and then we carried out Monte Carlo Simulation (MC) in combination with Latin Hypercube Sampling (LHS). We identified the sensitive parameters using the MC LHS method and estimated the structural uncertainty of the model. We validated the hydrology models in both time and space, and we validated the inorganic nitrogen sub-model of the INCA-N model with the data of an independent period. The modelling chain was able to reproduce 59% of the variability of average nitrate concentrations in the Tetves Creek for the validation period.
After validation, we examined several climate change, land use and nitrogen supply scenarios and their combined effect. We concluded that the impact of the predicted climate change might be more decisive in the study catchment than that of the change in land use, however, the extent and sign of the impact would depend on the characteristics of the selected climate scenario. Another important finding is that the impact of mitigation measures can be more pronounced in the future than under current climatic conditions.

Keywords: nitrate load, INCA model, scenario analyses, climate change, land use change, mitigation measures

MODERN HYDROGRAPHIC AND WATER MANAGEMENT ZONING OF UKRAINE'S TERRITORY IN 2016 – IMPLEMENTATION OF THE WFD-2000/60/EC

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Planned activities on implementation of EU Water Directives are being implemented in Ukraine. The schedule of achievement of goals for each of the directives, which specifies the terms of realization of certain tasks, has been developed. The most ambitious task is the implementation of the Water Framework Directive 2000/60/ EC, which are divided into stages in Ukraine: 1) 2014-2017 - is the adoption of national legislation and determination of the authorized body; fixing at the legislative level the notion of unit of hydrographic zoning of the territory of the country; to develop a position on the basin management with the assignment of appropriate functions on it.; 2) 2014-2020) - is definition of areas of river basins and creation of mechanisms for management of international rivers, lakes and coastal waters; analysis of the characteristics of river basin districts; introduction of water quality monitoring programs; 3) 2014-2024 - is preparation of river basin management plans, public consultation and publication of these plans. From the three above-mentioned stages of the implementation of the WFD 2000/60/EU in Ukraine, the period of implementation of the first phase (2014-2017) - the legislative-organizational. Briefly describe its results.

On October 4, 2016, the Verkhovna Rada of Ukraine adopted the Law of Ukraine "On Amendments to Certain Legislative Acts of Ukraine on Implementation of Integrated Approaches in the Management of Water Resources Based on Basin Principle" (No. 1641-VIII), which introduced a number of changes to the Water Code of Ukraine in 1995, aimed at introducing the provisions of the Water Framework Directive of the European Union into the practice of water resources management of the state. This law supplemented the Water Code of Ukraine with a number of new terms and concepts implemented with WFD 2000/60/ EC, officially approved the hydrographical zoning of the territory of the state, recognizing that the river basin district is the main unit of management in the field of water use and protection.

Hydrographic zoning is a division of the territory into a hydrographic unit, which is carried out for the development and implementation of river basin management plans. In Ukraine, 9 river basin districts are legally established: Dnipro river basin district; Dniester river basin district; Danube river basin district; Southern Bug river basin district; Don river basin district; Vistula river basin district; river basin district of the Crimea; river basin district of the Black Sea coast; river basin district of the Azov Sea coast. The Ministry of Ecology and Natural Resources of Ukraine in 2017 allocated 13 sub-basins within the four river basin districts: the Dnipro – 5 sub-basins, the Danube – 4 sub-basins, the Don – 2 sub-basins, the Vistula – 2 sub-basins

Water management zoning – the division of hydrographic units into water management areas, which is carried out for the development of water management balances. Areas of land are allocated within river basin districts, taking into account the basin principle of management, administrative-territorial structure, physical and geographical conditions and economic activity. In 2017, 132 water management areas were allocated. According to the river basin districts, the distribution of water management areas is as follows: Dnipro – 59 water management areas; Dniester – 12; Danube – 8; Southern Bug – 11; Don – 20; Vistula – 3; rivers of the Crimea – 8; rivers of the Black Sea coast – 4; rivers of the Azov Sea coast – 7 water management areas.

Modern hydrographic and water management zoning of the territory of Ukraine approximates the management of water resources of the state to European requirements.

IMPLEMENTATION OF THE WATER FRAMEWORK DIRECTIVE IN ODESSA REGION

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The water management system of Odessa region is realized in the context of object using the basin principle. The basin management principle is a modern approach to water management, according to which the basic unit of management is the river basin area.

Presently, Basin Water Management Department (BWMD) of the Black Sea and the lower Danube are established and function, and the Basin Council of the Black Sea Rivers was established in October 2018.

The importance of such formation as The Basin Council is, first of all, in the implementation of the principles of basin water management. It is the goal of the Water Framework Directive (accepting it, Ukraine realizes the intention of joining the EU). The main aim of the Council is implementing the principles of integrated water resources management in river basins by taking coordinated decisions on water management policy for the basin with involvement in the management of local authorities in the use and protection of water resources, public and environmental organizations and research institutions.

The system analysis of the current status of river basins in Odessa region and the organization and management of water resources permitted to outline the most actual problems that need to be soluted, namely:

- The Expansion of activities of basin water management and its approach to water use within the Framework Water Directive;
- The work improvement concerning the water quality control in rented reservoirs;
- The monitoring of condition of lakes, lakes-estuaries, taking into account the geological, hydrogeological, engineering-geological, hydrogeochemical and environmental component;
- The participation in the Black Sea basin's medium and small rivers certification;
- The study of possible excessive water loss from the reservoirs. It explains causes, consequences, solutions and minimizes the flow of public and private funds (Koziysky, Nerushaysky, Dmitrovsky and Baraboysky reservoirs).
- The adaptation of current legislature to the conditions of transition to state water management by basin principle and adaptation of regulations concerning the transboundary flood forecasting as well as dry years and of accounting and water monitoring regulations;
- The development of necessary regulatory and methodological documentation concerning the new administration, and the reform of existing ones;
- The Drafting development of state, basin (including interstate) and regional programs concerning the water use and protection;
- The development of the draft management plan of water use, protection and recovery of water resources.
- At present global and regional climate change is increasingly evident in all areas, including the hydrological regime of rivers, so their program of strategic development within the Odessa region, which is currently absent, must be developed.

Keywords: water resource management, Framework Water Directive, Odessa region

WATER RESOURCE MANAGEMENT OF FLOODPLAIN LAKES IN DANUBE REGION (ON EXAMPLE YALPUG-KUHURLUY)

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The Ukrainian Danube Region is characterized by its unique natural resource potential. The presence of significant water resources of the Danube and the Danube lakes in arid climate conditions of the region largely determined the history of the Ukrainian Danube region and the socio-economic prospects of the region at present. The system of lakes Yalpug-Kugurluy is the largest natural freshwater reservoir in Ukraine. Water management activities undertaken in the late 60s of the last century, caused significant changes in the hydrological regime of lakes and negatively impacted on its hydrochemical state. At present, the quality of water in the lakes in most cases does not meet the requirements water state standards for irrigation. The important task is the restoration and rational use of natural resources lakes Yalpug-Kugurluy, by improving its hydrological and hydrochemical regimes.

The main cause of the unsatisfactory water quality in the lake can be considered low water exchange and the inconformity of water levels in the lake, those that were designed in the 80s of the last century. It is necessary to note that one of the main factors that determine the ecological state of the lake Yalpug is the impact water of small rivers with high mineralization and significantly contaminated, especially r. Yalpug (by the way 90% of the basin is in Moldova).

Justification scientific and methodological basis to determine the components of the water and salt balance can be used to model the optimal regime of functioning of Lakes Yalpug – Kugurluy. Water balance of Lake Yalpug mainly determined by the inflow of water through: precipitation (29 to 60%), free circulation water of the Danube River (35 to 68%) and by the outflow through evaporation from water surface (39 to 86%). The water exchange with the river Danube is the main source of water exchange and maintains water quality.

The greatest impact on the mineralization system of lakes Yalpug -Kuhurluy have the inflow of salt water from small rivers, rain water and from Danube. Influx of salts with Danube waters, for the period from 2006 to 2014 ranges from 33% to 67%. Influx salt water from small rivers varies from 10 to 41%, slightly lower values with precipitation; they vary from 15% to 33%. In the outflow part of salt balance during calculating period (2006 to 2014) the highest percentage discharges of salt with filtered water into the banks - its vary from 21 to 91%. The loss of salts along with discharges to the Danube varies from 0.0 (in the years 2007, 2011, 2012, 2014 when there were not discharges) to 85%. The loss of salts along with the water intake is varying from 3 to 15%.

For further operation of the lakes Yalpug-Kugurluy can recommend the following measures:

- To support the water salinity in lakes - reservoirs at 1.0 g/dm^3 need to restore irrigation and filling its water from Danube
- Need to clear the natural branches to restore water circulation with the Danube River
- The strengthening work within an international agreement between the Government of Ukraine and Moldova on cooperation to improve the condition of water bodies
- The development at national and regional and possibly international level a comprehensive program for rehabilitation of lakes Yalpug and development of measures for improvement of both the waters of lake and its basin

Keywords: water and salt balance, Ukrainian Danube Region, floodplain lakes.

INTERNATIONAL POSTGRADUATE COURSE ON FLOOD MANAGEMENT AT THE RIVER DANUBE BASIN

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The Danube Strategic Project Fund (DSPF) was founded with the idea to serve as facility that will support the implementation of transnational strategic projects which are aligned with the objective of the EU Strategy for the Danube Region (EUSDR). The most significant activity in the Priority Area 5 is in the field of environmental risks. The activity should facilitate the flood protection of the Region and to enhance the flood safety of the whole Danube Basin

The lack of the dissemination of specific knowledge and practical solutions in flood protection hinders the implementation of EU Floods Directive and the Danube Basin Flood Risk Management Plan. Floods are amongst the major issues in the Danube river basin, if not the most significant.

Numerous floods have happened in the last two decades in almost all countries in the Danube River basin. Many of them were very huge, although there had been even larger ones during the long history, what was analyzed in details. In addition to huge floods in the Danube River (2006, 2010, 2013, 2014), even larger ones had happened along the major tributaries of the Danube River in its middle course such as those in the Tamiš River (2005), the Tisza River (2006), the Sava River (2005, 2010, 2013, 2014), as well as in the Sava River's principal tributaries: the Drina River (2010), the Kolubara River in 2014. Damages topped billions of EUROs and even worse casualties.

Management of floods is usually based on harmonized flood defense planning, forecast procedures and co-ordination of the activities of different institutions on the national and international level. Basic documents related to flood issues, that have been already developed in the EU, include the EU Floods Directive and the Danube Basin Flood Risk Management plan. The EU Strategy for the Danube Region (EUSDR) recognizes the importance of flood management. Thus, the Danube Strategic Project Fund (DSPF) supported the InterFloodCourse Project which aimed at the development of a curriculum and training material for the international, basin-wide course on flood management.

An International postgraduate course concerning flood management at the river Danube basin is designed aiming at coordination of education, information, forecasting and preparedness for floods at, as the largest scale phenomenon within the EU Danube Strategy. The project comprises preparation and exchange of experience and knowledge of the numerous national authorities aiming at improved coordination during forecast before and during floods at the Daube and its tributaries. Such a system should be a common basis for transboundary coordinative management. The aim is comprehensive preparation and improved mutual coordination of flood management including help and trans border support for an establishment of sustainable system protection of people, resources and assets at the entire Danube basin.

It should be emphasised that there is a strong need for harmonization of flood risk management in the entire Danube River Basin which is approximately 800.00 sqkm large (Figure 1).

The curriculum within the InterFloodCourse Project is developed by experts from 7 countries basin-wide, who have long experience in water management education, research and engineering practice. Apart from the course curriculum, the team of experts prepared course materials in the book of which covers numerous aspects of the flood management Additionally, the course material provides an overview of impacts of climate change on floods and those of flood duration and magnitude on the environment, navigation, urban infrastructure systems and flood control structures. Various

topics are complemented with examples demonstrating practical experience on the Danube River and its tributaries in Hungary and Serbia. This has been prepared, coordinated and edited by the two Project partners: the Faculty of Water Sciences of the National University of Public Service of Baja and the Faculty of Civil Engineering of the Belgrade University.

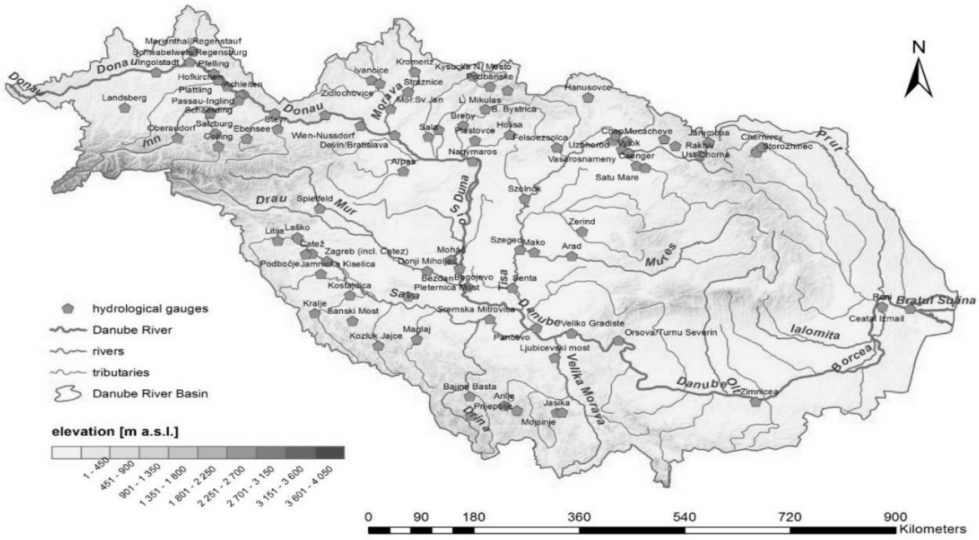

Figure 1. Gauging stations on the Danube River and its tributaries

The Course is offered at provision to interested parties and state agencies, who will benefit both from general and advanced knowledge in river hydrology and hydraulics, including statistics, sediment, soil and ground data, and different flood forecast aspects. In addition, reflects of flood toward infrastructure systems, such as navigation and municipal hydraulic systems and environmental damages either with global and/or climate changings at the Danube catchment.

The target of the project is to harmonize methodologies and foster academic mobility of engineers in training. The result is a comprehensive flood management curriculum that offers a professional development for engineers. The DSPF project will provide the possibility for common education based on EU directives, EUSDR PA5 and DFRMP needs, as well as on the extensive operative experience of lecturers.

The International Postgraduate Course on Flood management will be implemented in co-operation of the two partners, Hungarian National University of Public Service Faculty of Water Sciences, Baja, Hungary, and University of Belgrade, Faculty of Civil Engineering, Serbia. The course will be offering an international overview for participants.

The DSPF project ended in January 2019. The start of the International Postgraduate Course on Flood management is planned for the academic year 2019/2020. The application procedure will be managed by the lead partner, so applications for student admitting will be at National University of Public Service (NUPS) Faculty of Water Sciences, Baja, Hungary.

The International Postgraduate Course on Flood management will involve postgraduate Engineers (preferably Civil engineers) with a BSc degree or higher.

During last floods it was obvious that governmental and private companies were not prepared. designed education for preparation, forecast and mobility of people and knowledge is needed for flood management in the Danube River Basin,

Key words: Danube basin; Danube Strategy; floods; education; management; coordination.

GRAPHICAL METHODS OF ESTIMATION OF THE HOMOGENEITY AND STATIONARITY OF AVERAGE ANNUAL FLOW IN THE RIKA RIVER BASIN

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Estimation of homogeneity and stationarity of river runoff are the unresolved problems of hydrology, because statistical methods have limitations, so sometimes it is incorrectly to applied their to hydrological series, to obtain reliable results. In the context impact the global and regional climate changes on the water regime of rivers that leads to break of the stationarity of observations series, an important task is to study the tendencies of river runoff.

In this study the new methodological approaches based on the using of hydro-genetic methods for estimation the homogeneity and stationarity of hydrological series were used. This approach was developed by Gorbachova. We analyzed the long-term (since the beginning of the observations to 2015) average annual runoff of the small mountainous rivers of the Danube River Basin (7 gauging stations) and its cyclical fluctuations during a long period of time. The main result is that series of observations are homogeneous and stationary. However, not all series of observations were representative for determination of the stable average value. The long-term fluctuations of the average annual runoff at all gauging stations is synchronous. Therefore, the climatic conditions of the flow formation are homogeneous. However, these fluctuations are not always synchronous phase. We found out that the average annual runoff in this basin fluctuates and has decreasing tendency in the last years. It is due to cyclical fluctuations of the river flow.

Keywords: graphical methods, hydro-genetic analysis, small catchments, homogeneity and stationarity, annual average runoff

LONG-TERM CHANGES OF WATER QUALITY INDICATORS IN THE DANUBE RIVER KILIYA DELTA

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Variability of hydrological and chemical values of marine coastal and estuarine water is the product of both natural and anthropogenic influences. Multi-annual (decadal) trends may be connected with climate change effects (water warming, acidification etc.) as well as systematic reducing of pollutant emissions and improvement of waste water treatment. Water quality and pollution parameters measured in the Danube delta describe the amount of nutrients and pollutants inflowing to the Black Sea with the largest river water discharge.

In the framework of the international project EMODNet Chemistry, the array of hydrological and chemical data obtained in 1992-2016 was formed. Surveys within the Danube delta were performed by the Danube Hydrometeorological Observatory in frameworks of State environmental monitoring. Spreadsheets were created containing the meta-information and data on all measured physical and chemical parameters. Data quality control was performed by UHMI experts and the metadata bases on the websites of EMODNet Chemistry and Sea Data Net projects were expanded. Data of these observations in the format of Ocean Data View (ODV) were uploaded to the UHMI data server.

In order to analyze the long-term changes of physical and chemical water quality indicators, 8 representative monitoring stations within the Kiliya delta area were chosen. Water samples on some of them were taken not only from surface layer but also from bottom and intermediate depths.
Three groups of indicators were considered: 1) standard water chemistry (temperature, dissolved oxygen, pH and alkalinity); 2) dissolved nutrients (phosphate and total phosphorus, silicates, nitrites, nitrates, ammonium and total nitrogen); 3) technogenic pollutants (total petroleum hydrocarbons, anionic detergents and total phenols).

Statistical analysis of time series was executed by means of ODV and XLSTAT software. Standard statistics were estimated (mean value, standard deviation, LS-estimate of linear trend slope and intercept, Pearson's correlation coefficient and determination coefficient) and also non-parametric Mann-Kendall (MK) trend test (including Kendall's correlation coefficient, Sen's slope and intercept for the trend line).

Referring to MK test results, no trends were observed in water temperature and pH while weak positive trends in dissolved oxygen content and alkalinity were traced. So, comparing with other marine coastal zones of the Black Sea NW part, global warming and acidification did not affect the Danube delta because of intensive interaction processes between riverine and marine water within the branches and seashore area. Nutrient contents demonstrate clear tendencies (with exception of nitrites): silicates, nitrates and total nitrogen – to increase; phosphate, total phosphorus and ammonium – to decrease. Most notable long-term changes were obtained in pollutants content time series – all of them were significantly decreased under depressed anthropogenic load during the time interval of 1992-2016 years.

Keywords: Danube delta, water chemistry, nutrients, pollutants, statistics, long-term trend.

CHEMICAL COMPOSITION AND WATER QUALITY IN THE RIVERS OF THE DANUBE AND DNIEPER BASINS UNDER ANTHROPOGENIC PRESSURE AND CLIMATE CHANGES

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The period from early 1990 to nowadays is unique for the natural environment of Ukraine, in general, and aquatic ecosystems, in particular. The point of issue is a significant decrease in the levels and rates of the anthropogenic impact. The main emissions of chemicals into various natural environments were a result of functioning energy sector in the Ukrainian economy. The economic downturn, which began in 1991, led to a significant reduction in energy consumption and, consequently, a decrease in emissions of pollutants into the environment. For example, only from 1990 to 2000, coal mining in Ukraine decreased from 155 to 80 million tons, and total energy consumption decreased from 326 to 145 million tons of reference fuel.

From 1990 to 2015, the total emissions of nitrogen compounds decreased from 2.4 to 0.56 million tons per year, and sulfur dioxide compounds – from 2.2 to 0.75 million tons per year. Concentrations of these substances in atmospheric precipitation and the rivers of the Dnipro and Danube basins decreased almost synchronically.

Based on the long-term information on the chemical composition and precipitations, the hydrochemical zoning of the Ukrainian surface water had been carried out by the elements of salt composition, nitrogen and phosphorus compounds, and dissolved organic matter.

In addition to assessing the influence of anthropogenic pressure, the climatic and geological conditions were indentified playing the key role in formation of the ion composition and the overall mineralization of the surface water in the Dnipro and Danube basins. The nature of the soil cover, the ratio of precipitation and evaporation in combination with different regimes of groundwater levels and air temperature are the determining factors for changes in concentration and the ratio of major ions and the magnitude of water salinity.

It has been shown that hydrocarbonate-calcium water with mineralization within 250-500 mg/dm3 and a balanced content of basic ions is formed in the rivers with a soil washing regime and a carbonate composition of water-bearing rocks. With a decrease in precipitation and an increase in air temperature from the northwest to southeast of Ukraine, there is a change in soil cover from sandy podzolized soils to chornozem. These soils have a high content of sulfate and chloride salts of sodium, magnesium, and calcium and are also characterized by a high capacity of cation exchange.

These factors lead to a change in the chemical composition of surface waters from the hydrocarbonate-calcium type to sodium-sulphate one. Increase of water salinity in the rivers of the southern and southeastern regions of the Dnipro basin was observed. The reason for this was most likely a rise of summer temperatures and an increase in the share of the underground contribution to runoff in the last decade.

New data on the influence of the water optical properties on the intensity of hydrological and physical-chemical processes have been obtained. Increasing the of dissolved organic substances by humic origin cause increasing the water color affected significant decrease in the photic layer. This leads to the phytoplankton inhibition and the subsequent change in the physical and chemical conditions of the aquatic environment - gas regime, redox conditions, equilibrium state of the basic hydrochemical systems, co-existing forms of substances, the direction of transformation and interphase distribution of chemical elements.

The features of physical-chemical processes determining water chemistry in the Dnieper and Danube basins under climatic changes are shown.

THE SEPARATION OF THE OBSERVED CONCENTRATIONS OF CHEMICAL COMPONENTS OF SURFACE WATERS INTO COMPONENTS: CONCENTRATIONS OF THE CLIMATIK NORM, CONCENTRATIONS DUE TO CLIMATE CHANGE, CONCENTRATIONS OF ANTROPOGENIK ORIGIN

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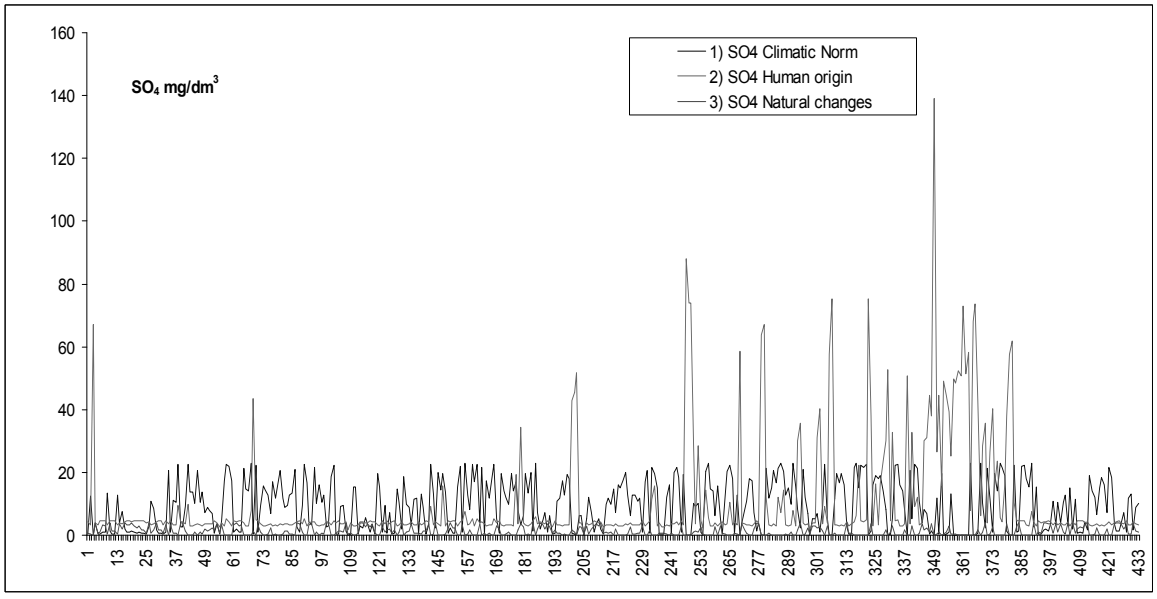
The theoretical basis for testing the hypothesis of a probabilistic relationship between the values of concentrations of the climatic norm, the values of concentrations due to climate change, and the concentrations of anthropogenic origin, as components of the observed values of concentrations, has been developed.

The method of separation is based on the axiom of A.N. Kolmogorov. The hypothesis is that the law of statistical distribution of values of observed concentrations is a convolution of statistical laws, namely: the law of statistical distribution of concentration values, natural origin and the law of statistical distribution of concentration values, of anthropogenic origin. At the same time, the law of statistical distribution of concentration values, of natural origin is also a convolution of the law of statistical distribution of concentration values belonging to the climate norm and the law of statistical distribution of concentration values due to climate change. An analytical model of Generalized Gaussian 1 is defined, which corresponds to the laws governing the formation of the chemical regime of water bodies and allows for stochastic analysis. Identifying by statistical parameters, i.e. by mathematical expectation, standard deviation and excess, the laws of statistical distributions of the constituted components were determined by the probabilities of actual concentrations, natural concentrations, anthropogenic concentrations, probabilities of climatic norm concentrations and probability of concentrations due to climate change. Then, by means of the fourth (IV) axiom of A.N. Kolmogorov, the concentrations of the analyzed components were calculated. Testing of the proposed methodology was carried out on the example of observations of the concentrations of sulfates SO_4 mg/dm^3 at the Pokoshichi point on the Golovesnya River for the period from 03/03/1954 to 12/11/2010 (figure).



The components of the observed concentrations of SO_4 mg/dm^3: 1) the concentration of the climatic norm; 2) the concentration of human origin; 3) concentration due to natural climate change.

ABIOTIC TYPOLOGY OF THE RIVERS AND LAKES OF THE UKRAINIAN SECTION OF THE WESTERN BUG RIVER BASIN AND ITS COMPARISON WITH RESULTS OF POLISH INVESTIGATIONS

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The Ukraine-European Union Association Agreement (2014) provides for the application in Ukraine of European standards and normatives. In the area of water use and water protection the main document is the EU Water Framework Directive (EU WFD).

The Western Bug river basin, which belongs to the Vistula basin, is located on the territory of Ukraine (28% of the catchment area), Poland (46%) and Belarus (26%). Abiotic typology of water bodies is an important task for the subsequent stages of the selection of water bodies and monitoring. The purpose of this investigation was to perform the abiotic typology of rivers and lakes in the Ukrainian part of the Western Bug basin and to coordinate the results obtained by Polish investigations.

The river basin of the Western Bug is mainly located within the Eastern-Baltic-Belarusian and Central Pol lowlands on the moraine-old glacial sediments. Only the upper part of the basin occupies the high-altitude areas of the Volyn-Podolsk Upland on the cretaceous sediments, as well as a small part of the Lublin-Lviv Upland on the loess.

The completed investigation, which are based on the requirements of the EU WFD and rivers typology systems adapted in Ukraine and Poland, allowed us to identify: for the Western Bug river basin within Ukraine 9 abiotic river types, within Poland - 7. In the Western Bug basin is dominated by small and medium rivers of lowlands and uplands of the Eastern Plains on silicate rocks. The Western Bug belongs to very large rivers, the Poltva, the Rata and the Luga belong to large rivers.

Within the Ukrainian part of the Western Bug river basin, there are only 2044 rivers, of which 2010 (98.35%) are small rivers. The length of the majority of them (1966 rivers are small) doesn't exceed 10 km. Middle rivers are 1.45%. Large and very large rivers are 0.15% and 0.05% of their total, respectively.

Should be noted that the complex studies of lakes in the Western Bug river basin in Ukraine are worse than Polish. The available information about lakes on the Ukrainian territory is often represented only by their morphometric characteristics. In the Ukrainian part of the Western Bug basin the majority (48 lakes or about 71%) of the existing 68 lakes are classified as very small according to the EU WFD. There are 9 small and 9 medium lakes (13% of the total amount), two large lakes (the Svitiaz and the Pulemetskoe) - 3.0%. Generally, in the Ukrainian part of the Western Bug basin 8 abiotic types of lakes were identified. Shallow and medium depths are dominated by small and medium lowland lakes on silicate rocks.

An important prospect for further work in this direction is to conduct comprehensive hydroecological research of lakes in the Western Bug river basin in Ukraine for their more detailed typology according to the EU WFD.

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NITROGEN AND PHOSPHORUS LOAD IN THE DNISTER BASIN IN UKRAINE

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Nutrients are essential for the agricultural production. Among them nitrogen, making up 78% of the Earth's atmosphere, and phosphorus play a pivotal role to ensure plant growth. Human activity has greatly contributed to the increase in productivity of agricultural land what caused changing of nutrients natural cycle, disturbing natural systems and affecting human health.

Water pollution by nutrients causes eutrophication, acidification and biodiversity loss in fresh water. Nutrients can reach freshwaters through a number of pathways which are conditionally divided into two large groups of point and diffusive sources. The first are the quasi-stationary in space and time (sewage discharges of municipal and industrial treatment facilities) whereas the nutrient load delivered from diffuse sources depends strongly on hydrological processes and landscape. In contrast to point sources, which are mainly associated with anthropogenic factors, diffuse inputs depend on both natural processes and the influence of human activity.

The Dnister river, the third largest river in Ukraine which basin is shared with Moldova, has been selected for the calculation of phosphorus and nitrogen load. The upper part of the Dnister is mainly located within the slopes of the Carpathian Mountains, the middle part is located within the Podilsk and Pridnistrovsk hills and the lower part is located within the Black Sea lowlands.

Monitoring data of water chemical composition and precipitation for the year 2017 were used as initial information. The main pathways of nutrient input were considered: point sources, untreated rural wastewater, precipitation, agricultural areas (cropland and grassland), forested territory, artificial surfaces and associated area, erosion process. There were nearly 400 points sources in the Dnister river basin. Among the main sectors of the economy the largest number of wastewater discharges is typical for public utilities – 67 %, agriculture and industry contributes 16 % of total wastewater discharges.

As follows from the obtained results the main part of the nitrogen pollution was delivered by the diffusion sources of agricultural origin. In the middle and lower parts of the basin their rate considerably exceeds the corresponding values in the upper mountainous area. A point sources of pollution prevail only in the basins of Bystrytsya and Bystrytsya Tysmenyska and make up 55% and 32% of total nitrogen load correspondly.

The role of forests is quite significant in the Carpathian part and reach 20 to 30% of total load, in particular in the river's basins of Limnytsa, Stryy, Svicha. The forest effect on nitrogen flow in the Podilsk part varies from 1 to 4%. Pollution by phosphorus compounds of Dnister basin rivers occurs mainly from point sources in the Carpathian part. The percentage of point sources in the rivers Bystrytsa, Seret and Bystrytsa Tysmenyska ranged from 60 to 81%. In Podilsk and the lower part of the Dnister a phosphorus load is mainly occur from agricultural areas.

Keywords: Nutrients, nitrogen, phosphorus, load, point and diffuse sources, Dnister

THE MODERN STATE OF THE HYDROCHEMICAL REGIME IN THE KILIYA DELTA OF THE DANUBE RIVER

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The chemical composition of water in the Danube River depends on the combined effects of natural and anthropogenic factors. A characteristic feature of the Kiliya delta is the high content of suspended solids, which are mainly mineral nature, contamination by metal compounds, nutrients and other specific chemical compounds, penetration of seawater into the delta branches.

Dissolved oxygen concentration has been changed after the regulation of the Danube River. Eutrophication of the Kiliya delta is caused by a decrease in the content of suspended solids and an increase in the concentration of nitrogen and phosphorus compounds. Algal blooms and oversaturation with oxygen of water (more than 100%) have become more frequent, and there is also dissolved oxygen deficiency. There is an increase in the pH values of the water. The salt content of water in the Kiliya delta of the Danube River has changed since the middle of the 20th century. Its average values increased from 287 to 398 mg/l. There is a periodic penetration of salt water in the Prorva and Bystryy branches. The highest concentrations of ammonia nitrogen, nitrite ions, nitrate ions and inorganic phosphorus were observed from the end 70 to the beginning of the 90s of the last century. Their concentration during this period was on average 0.44-0.62, 0.044-0.074, 0.98-1.66 mgN/l and 0.160-0.280 mgP/l. Currently, the concentration of ammonium nitrogen, nitrite and nitrate ions in the water of the Kiliya branch above the Vilkovo town does not exceed 0.010, 0.003 and 0.560 mgN/l. This is consistent with the tendency to reduce the concentration of ammonium nitrogen and nitrite ions, while the content of nitrate ions is still high.

The values of chemical oxygen demand when using potassium permanganate and potassium dichromate in the water of the Kiliya delta are in the range of 1.4-2.4 and 6.2-12.2 mgO/l, which corresponds to the average values of these indicators over a long period of time. The content of dissolved organic matter (DOM) is in the range of 4.6-9.2 mg/l. Humic substances (HS) is the dominant group of DOM. The concentration of HS is 3.1-7.7 mg/l, and their share reaches 54.8-85.6% of the total DOM content. The concentration of HS in the water of the Kiliya delta's branches decreases downstream. The fraction of HS with a molecular weight of 20-5 kDa dominates, the share of which is about 50% of their total content.

The greatest pollution of water with metal compounds in the Kiliya delta was observed in the second half of the 80s and at the beginning of the 90s of the last century. At present, the concentration of the dissolved form of metals is (µg/l): Al – 24.0-95.0, Fe – 35.0-230.0, Mn – 1.9-21.5, Cu – 5.5-55.7, Cr – 4.3-21.5. The studied metals, except Cu(II), migrate mainly in a suspended state. The content of their suspended form is in the range of 600-9830, 130-2820, 3.6-81.5, 0.6-9.8 and 4.8-23.5 µg/l. The ratio of suspended and dissolved forms of metals has changed little over time. Al, Fe, Mn, Pb and Cd are predominantly transported in the composition of suspended solids, while for Cu and Cr this is less characteristic. The share of the labile fraction of dissolved metals as potentially toxic for hydrobionts is on average 34.7% $Al_{dissolv}$, 31.1% of $Fe_{dissolv}$, 68.8% of $Mn_{dissolv}$, 28.5% of $Cu_{dissolv}$, 32.5% of $Zn_{dissolv}$, 9.5% of $Pb_{dissolv}$, 33.2% of $Cr_{dissolv}$ and 43.5% of $Cd_{dissolv}$.

HS play the main role in the complexation. In the composition of complexes with HS 51.6-63.9% of $Al_{dissolved}$,, 44.7-63.0% of $Fe_{dissolved}$ and 29.2-55.3% $Cu_{dissolved}$ were detected. At the same time, metal complexes with a molecular weight of <1 kDa dominate. Therefore, the metals in the water of the Kiliya delta's branches are in a bounded state due to the complexation with DOM or adsorption on suspended solids. Due to this, their chemical and biological activity is significantly reduced, which is important from an environmental point of view.

Keywords: dissolved oxygen, salt content, nutrients, metals, Kiliya delta of the Danube River