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Long-term tendencies and annual distribution of water regime, suspended sediments and mineralization of the Low Danube within the Ukrainian part

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Introduction

This investigation aims at studying the individual components of the hydrological and hydrochemical regimes of the Low Danube River (within Ukraine) in connection with the widespread use of the river's water for water supply and irrigation in the southern region, as well as to ensure more effective regulation of water-salt regime of the Danube lakes using the Danube River as a main source for their water renewal. One of important aspects includes the study of the regime of the Danube River's suspended sediments brought to its delta due to their impact on the formation of the delta at the river's mouth of as well as due to the impact on siltation of deltaic and pre-delta lakes and canals connecting the lakes with the Danube River (Hydrology of the Danube Delta, 2004).

The analysis of the current state of the hydrological regime in the Lower Danube shows that natural and anthropogenic changes which affecting the water discharge should be considered separately.

Anthropogenic factors are mainly related to hydraulic engineering structures which have been actively implemented since the 1960s and led to the regulation of the Danube River runoff (Best, 2019). Such structures caused a redistribution of the long-term runoff of the Danube River across its delta (Kiliya and Tulcea branches) with the increase of water content in the Romanian part of the delta (Tulcea branch) and its decrease in the Ukrainian part (Kiliya branch) (Cheroy, 2013).

The impact of climate change on the water regime of the rivers of the Danube Countries (especially in the territory of Ukraine) has been manifesting itself over the last thirty years of the retrospective period (Pekárová et al., 2019).

The paper (Grebin, 2010) considers 1989 to be a turning point in terms of the air temperature change in Ukraine and, accordingly, the rivers' hydrological regime change.

The purpose of the work is to study long-term and current trends related to changes in hydrological (water levels and discharges, suspended sediments runoff) and hydrochemical (mineralization) regimes of the Danube River within the Ukrainian interval from Reni to Ismail, internal annual distribution of water runoff, as well as suspended sediments runoff and mineralization during the years of varying water content.

Methodology

The statistical and mathematical methods were used to assess the characteristics of the long-term hydrological regime of the Lower Danube. The *F*-test (Fisher criterion) was used to assess the statistical homogeneity of the initial information. The assessment of cyclical fluctuations of river runoff was performed using the residual mass curves. Statistic parameters are calculated via the method of moments and the method of maximum likelihood.

Results

Thus, the verification of the homogeneity of time series of average annual, maximum and minimum water discharges was performed for different periods of water content of the Lower Danube. Such periods include the natural regime of river runoff (1840–1920), the least altered river runoff regime (1921–1960) and the most altered river runoff regime under the anthropogenic influence (1961–1989). The determination of climate change impact on the Lower Danube River allowed introduction of a new, present period of its hydrological regime (1990–2015) (Romanova et al., 2019).

According to *F*-test (at the significance level of 5%) time series of average annual water discharges at Reni and Ismail water gauge station (WGS) should be considered as uniform, i.e. the influence of anthropogenic factors and climatic change did not have a major impact on the annual river runoff of the Danube Delta as a whole. However, if we consider the different phases of water content separately, there are still some changes. For instance, the lack of uniformity of the time series of the maximum and minimum discharges may be observed over the period when hydraulic engineering

structures started to affect the river's hydrological regime (in 1961). At the same time, the influence of climatic changes on the river runoff in the late 1980s didn't have any influence on the time series of such water discharges.
Although the annual runoff series proved to be homogeneous in time, the analysis of the aggregate multi-year series (1840–2015, i.e. over the period of 176 years) of the Danube River average annual water discharges across its length from Reni to Ismail indicated the presence of a weakly expressed, almost two centuries long trend towards their increase.
The authors also performed the analysis of the cyclicity and uniformity of the annual water discharges in the course of time over different periods of the Lower Danube water content. The period of conventionally natural river runoff regime (1840–1910) may be considered as the one that has a negative trend, whereas the period of the least altered runoff regime (up to the 1960s) has a neutral trend. Over the period from the 60s to 80s of the last century (i.e. over the period of the most altered runoff regime and before the significant impact of climatic changes) a positive trend was observed. The period after 1989 (the period of significant climatic changes) had a trend towards a certain decrease of the annual river runoff up to 1994 and a slow increase (starting from 1995) of the annual river runoff across the lower course of the Danube River.
The study of long-term variation of maximum water discharges over the period of 1921–2015 showed that the maximum water discharges featured a slight increase. It should be also noted that the time series of observations are characterized by the period with negative trend (1921–1960) and the period with positive trend (1961–2015) of the maximum water discharge. In addition, the period of climatic changes (after 1989) is also characterized by a less intensive growth of maximum water discharges.
The construction of chronological charts of the minimum water discharges across the Danube River from Reni to Ismail allowed the identification of insignificant positive trends and synchronicity of their course over the interim period for both of the WGS. However, since the 2000s such synchronous trend was disrupted due to the redistribution of water discharge between the Danube Delta branches.
It was also established that the intra-annual course of average monthly water discharges of the Danube River at Reni and Ismail river sections during the high-water, middle-water and low-water years (for the combined series of data from 1960 to 2015) was characterized by the homogeneity of river runoff depending on the water content of a certain season. The study shows the presence of a pronounced trend to reduction of suspended sediments runoff of the Danube River at Reni (for the period of 1840–2015), with their most intensive decrease over the period of 1990–2015. Annual distribution of average monthly suspended sediments runoff of the Danube River for the years with typical water content (for the period of 1978–2015) showed that they have seasonal fluctuations. At the same time, there is a decrease in the suspended sediments runoff along the length of the river from Reni to Ismail. The long-term course of average annual mineralization values of the Danube River at Ismail (1981–2015) is characterized by their decrease against the background of a small increase in average annual discharges. As per the annual distribution of mineralization values associated with all water content groups there are the periods related to the phases of the river's yearly water regime during and the economic use of water (Shakirzanova et al., 2020).
Conclusion. Thus, the increase in the long-term period of the Danube River runoff within the interval from Reni to Ismail will contribute to the development of the region's economy and water supply, irrigated farming, regulation of the Danube Lakes filling with weakly mineralized river water. At the same time, the reduction of the suspended sediments runoff will restrain the siltation of the inlet canals connecting the lakes with the Danube River, which will improve the water renewal of the lakes with the river's fresh waters.

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