SIMILARITIES AND DIFFERENCES OF THE HYDROLOGICAL EXTREMES ON THE DUNA/DANUBE AND TISZA/TISA RIVERS (1921-2012)

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ABSTRACT. Similarities and differences of the hydrological extremes on the Duna/Danube and Tisza/Tisa rivers (1921-2012). In terms of the water management in Hungary, both rivers have a highlighted importance, which is also indicated by the fact that 50-55% of the territory of the country is divided between the two catchment areas. Though the Tisza is the tributary of the Duna River, its catchment area, its bed length, its typical discharges are smaller than those of the host Duna, but on the Hungarian territory there is no size difference between them. Thus, the catchment area of the Tisza River above the Hungarian-Serbian border (at Szeged) is 138.408 km^2, the catchment area of the Duna River above Budapest (at Nagymaros) is 183.534 km^2, so the spatial difference is aproximatively 25%. In the medium many years discharge the difference is almost three times, on the Tisza at Szeged it is 834 m^3/s, on the Duna, at Nagymaros is 2308 m^3/s. On the Tisza River, at Szeged the maximum discharge exceeds 75 times the minimum discharge, on the Duna River, at Nagymaros it exceeds 16 times, thus the Tisza water regime is more extreme than the Duna. The present study aims to analyse and compare main characteristics of the water regimes on the two rivers and those change tendencies in time on the longest period having reliable common data (1921-2012) concerning to the section of the Duna Nagymaros and Tisza Szeged gauge stations. Investigations carried out with hydrological statistical methods have been performed on a period of 92 years, further on within this entire period they have been performed on partly periods of 46 and 23 years as well. It have been analysed the linear trend of the yearly minimum and maximum water level and water discharge series, the temporal changes in the monthly frequency of the yearly extreme values occurred.

Keywords: minimum and maximum discharge, low flow periods, high flow periods.

1. INTRODUCTION

The Duna and the Tisza are rivers with an international importance, which cross countries members or not of the European Union. In terms of the water management in Hungary their importance equals, which also means that the territory of the country is divided 50-50% between the two river basins. The Danube catchment area upon Budapest exceeds with approximately 25% the Tisza catchment area upon the Hungarian-Serbian border. Due to the different

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geographical, climate and hydrological characteristics the size of the yearly water discharges, the extreme water level fluctuation and its development during the year are different as well.

In Hungary, due to the frequently occurring flood hazards the hydrological studies related to the flood waves are in the foreground of the researchers' interest. In the last decades many hydrological researches have been made for the Duna floods (1954, 1956, 1959, 1963, 1965, 1975, 1991, 2002, 2006, 2013) and the Tisza floods (1970, 1984/85, 1993, 1995, 1998, 1999, 2000, 2001, 2006, 2010, 2013) as well.

Fig. 1. The geographical position of Nagymaros and Szeged gauging stations in the Danube basins

As regards the water shortage developing in the extreme dry periods and the increasing water supply needs, in order to increase the efficiency of the water management it is needed the knowledge related to the low water fluctuation and the dry periods. Both the Hungarian National Water Management Framework Plans (OVF-VIZITERV 1954, OVF 1965, OVH 1984) and the Water Basin Management Plan (VKKI 2009) carried out in the frame of the EU Water Framework Directive contain data concerning the low water supply, but do not contain detailed statistical analyses on the characteristics of the low water events nor on the development in time of the low water discharges. As regards the Duna and Tisza sections in Hungary, in the second half of the 20th century and the first decade of the 21st century only few analyses have been carried out on this topic. In the recent years the daily main hydrological statistical characteristics of the low water discharge have been also analysed both on the Duna (Konecsny 2011) and the Tisza, as well as the characteristic sections on the tributaries (Konecsny 2010, 2013, Konecsny-Bálint 2010). The characteristics of the extremes of the water fluctuations have been analysed on the two tributaries of the Tisza River, the Hernád (Konecsny 2011) and the Túr (Konecsny-Nagy 2011).

2. THE MAIN HYDROGRAPHICAL AND HYDROLOGICAL CHARACTERISTICS OF THE DUNA AND TISZA RIVERS

The Duna catchment area at Nagymaros is 183.534 km^2, the catchment area of its biggest tributary, the Tisza River, at Szeged is 138.408 km^2. Thus the catchment area of the Duna section at Nagymaros exceeds with only 25% the values concerning the Tisza section at Szeged.

The mountainous section of the Duna-valley represents only 36% of the entire basin, but it contributes with 75% to the Duna estuary discharge (Újvári 1964). A more advanced regulation on the 417 km long section in Hungary started in the 18th century and by nowadays the flood control has been built up on the main branch and the tributaries –excepting the high coastal sections. 32 dams were built on the Duna upon Nagymaros (Stancikova Alzbeta 2001). From 1992 the fluctuation on the section in Hungary is affected mainly by the Gabcikovo hydroelectric plant built in Slovakia and the associated reservoir (196 million m^3), but the main characteristics of the fluctuation are determined by the precipitation and the runoff (its quantity, its spatial and temporal distribution). Due to the bed regulation and the dredging carried out in the second half of the 20th century, the retention of a significant proportion of the drifts in the reservoirs established on the upper section of the river, the bed bottom level typically deepened 1,0-1,5 m, which decreased the low water levels as well.

The minimum water level detected by present at the Duna Nagymaros gauge was -53 cm (98,428 mBf), the maximum level was 714 cm (106,568 mBf), so the many years maximum water level fluctuation is 767 cm. In the period between 1921-2012 the medium many years discharge is 2308 m^3/s the minimum discharge of 586 m^3/s occurred in 1947, November 4th (in 1894. January 10th it was 531 m^3/s), the maximum discharge of 9150 m^3/s occurred in 1929, March 22nd (in 1891. March 9th it was 9790 m^3/s, in 2013. June 8th it was 9505 m^3/s). Thus the maximum discharge is 16 times higher (taking into account the entire 1883-2013 monitoring period, it is 18 times higher) than the minimum discharge. The variation coefficient indicating the variability of the yearly low water discharge is Cv=0,20.

The water resources of the Tisza River are mainly developing in the mountainous areas (Carpathians), its water level fluctuation is mainly affected by the rainy or dry periods typical in the temperate continental climate. The tendencies of Tisza medium and low water level time series are strongly decreasing; those of the high waters are minimum increasing. For example upon the Szamos mouth, at Tivadar the yearly low water levels decreased with about 1,5 m from the beginning of the 20th century. The decrease was mainly caused by the deepening of the river bed. The incision after the regulation can be observed on the entire length of the Tisza, excepting the dammed sections. At Szeged the level of Tisza has been dammed from 1976 when a barrage was established at Törökbecse. The minimum low water level record at Szeged occurred in 1946, October 10th and it was minus 250 cm. After putting it into operation, the minimum water level of 21 cm occurred in 1977, October 10th. The minimum discharge yet, of 57,8 m^3/s, was recorded in 1990, September 4th. In the period from 1921 to 2012 the many years medium discharge was 834 m^3/s, the minimum discharge of 57,8 m^3/s occurred in 1990, July 31st , the maximum discharge of 4350 m^3/s occurred in 1932, April 15th. The maximum discharge exceeded 75 times the minimum discharge. Thus the variation coefficient indicating the variability of the yearly low water discharge, Cv=0,42 is two times higher than the one at Nagymaros.

The yearly extremes of the Duna and Tisza flow regimes are indicated by the fact that in the high water years, for example in 2006, or in 1970 there occurred extremely high maximum discharge values (Nagymaros 9070 m^3/s, Szeged 2830 m^3/s), furthermore in the spring and summer periods significant flood waves followed each other (Fig. 2). In the low water years, for example, in 1934 or in 1961 the yearly characteristic discharges were low, at Nagymaros the minimum discharge was 874 m^3/s, at Szeged it was 110 m^3/s.

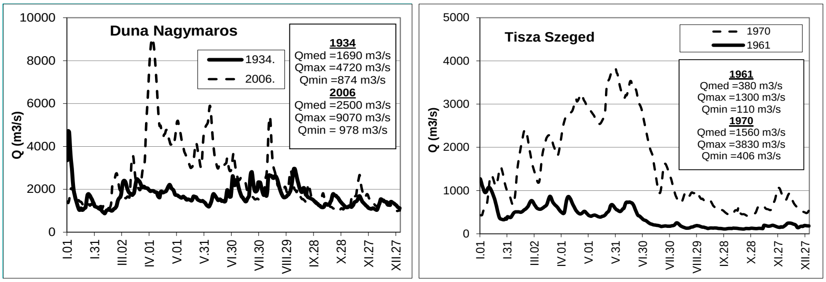

Fig. 2. Hydrographs of daily discharges and characteristic annual values for the high water year and low water year at station Danube Nagymaros and Tisza Szeged

The present study aims to analyse the main characteristics and the change tendencies in time of the two rivers' flow regime extremes, as well as to compare them on the common period having the longest reliable data (1921-2012) taking into consideration the Duna Nagymaros and Tisza Szeged gauge stations. Analyses hade been completed on the period of 92 years, as well as within the entire period on two part periods of 46 years and two part periods of 23 years. There had been analysed the linear trend of the yearly minimum and maximum water level, and discharge time series, the change in time of the monthly occurrence frequency of the yearly extreme values.

3. WATER LEVEL CHANGES OBSERVED AT THE TWO ANALYSED STATIONS

Analysing the available long time series, on the Duna section at Nagymaros in the period from 1921 to 2012 the yearly medium and the yearly minimum water levels significantly decreased (almost 1,5m), which was mainly caused by the river bed deepening. The maximum water levels practically do not indicate any changes. In the part period from 1921 to 1966, as regards the medium and the minimum water levels it cannot be indicated any change, but in the part period from 1967 to 2012 it can be observed a considerable decrease. In the both part periods the yearly maximum water levels indicate significant increase.

On the Tisza, at Szeged from 1921 to 2012, the yearly medium water levels and the yearly maximum water levels less increased, but the minimum water levels increased almost 3 m. From 1921 to 1966 the yearly medium water levels were characterized by a barley detectable decrease, the low water levels by a barley detectable increase, the maximum discharges were characterized by less water level increasing. In the period from 1967 to 2012 the yearly medium water level indicates a low water level increase, the yearly minimum water levels a significant increase, but the maximum water levels decreased.

Considering the two selected stations, there had been analysed the differences measured between the yearly extreme water levels. At the Duna Nagymaros gauging station, in the period from 1921 to 2012 the difference between the yearly maximum (H_{max}) and minimum (H_{min}) water levels varied between 182 cm (1950) and 745 cm (2006), and the yearly H_{max}-H_{min} time series indicated an increasing tendency. From 1921 to 1966 the differences slightly increased, but from 1967 to 2012 they significantly increased.

At the Tisza Szeged gauging station the difference between the yearly extreme values are bigger than the one at Nagymaros, between 195 cm and 1076 cm and the change direction is opposite to the one experienced at Nagymaros, namely decreasing. At Szeged, due to the damming effect, from 1967-2012 the yearly minimum water levels increased, and this caused the decrease in the difference between the maximum and the minimum as well. From 1921 to 1966 the differences slightly increased, between 1967 and 2012 they indicated a significant decrease.

4. THE EVOLUTION OF THE DISCHARGE EXTREMES

Analysing the yearly medium and extreme discharge time series, it was determined that on the Duna at Nagymaros in the period between 1921 and 2012 the yearly medium discharges decreased, the maximum and minimum discharges increased, while on the Tisza at Szeged all the three yearly discharge values increased (Fig. 3). Comparing the series of the two analysed stations, similar to the entire period, in the part periods 1921-1966 and 1967-2012 the change was typically opposite.

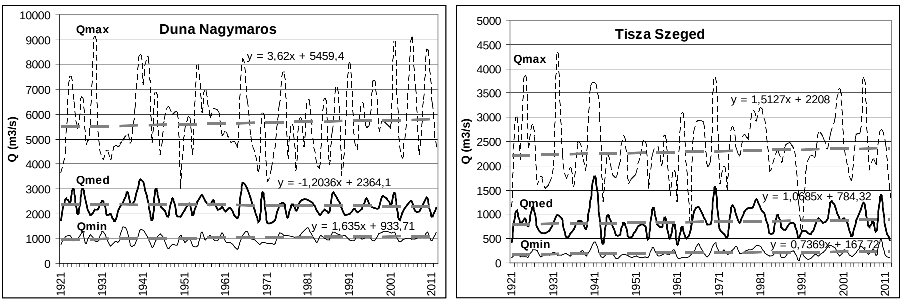

Fig. 3. The evolution of the yearly maximum (Q_{max}), medium (Q_m) and minimum (Q_{min}) discharges between 1921 and 2012

If the ten years averages of the yearly characteristic discharges are compared, on the Duna at Nagymaros the lowest ten years average of 2117 m^3/s occurred in the period between 1971 and 1980, while on the Tisza at Szeged in this years the maximum value of 945 m^3/s occurred. At the analysed stations the ten years extreme values of the maximum and minimum yearly discharges occur in different decades.

5. THE FREQUENCY OF THE DISCHARGE EXTREMES WITHIN A YEAR

Considering the distribution of the maximum and minimum discharges within a year, it can be determined that on the Duna at Nagymaros there is a difference of 17,4% between the months with the highest frequency (19,6 %) and the lowest frequency (2,2 %). In the case of the Tisza Szeged gauging station, between the months with the highest (30,4 %) and the lowest (0,0 %) frequency, the difference is higher, 30,4 %. The nearly two times difference (14,7 % and 30,4 %) also means that the Tisza at Szeged has more extreme flow regime than the Duna at Nagymaros.

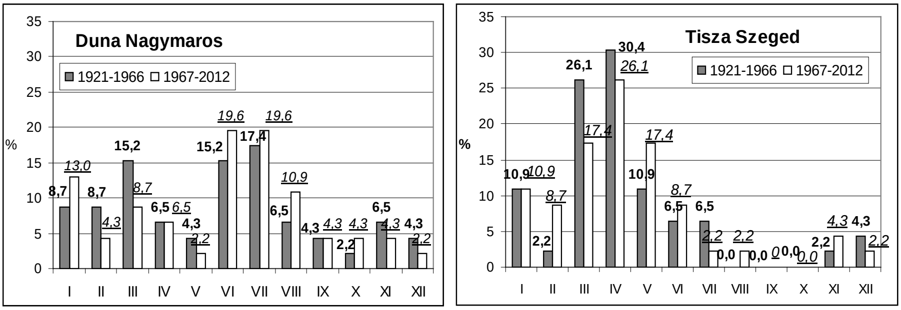

Fig. 4. The monthly frequency of the yearly maximum discharges in the part periods from 1921 to 1966 and from 1967 to 2012

In the case of the low water discharges the comparison between the two stations indicates that in the case of the Duna, the difference between the yearly minimum discharges in the months with the highest frequency (34.8%) and the lowest frequency (0.0%) is higher (34.8%), than the one in case of the Tisza, where the difference between the values (30.4% and 0.0%) is slightly lower (30.4%).

On the Duna River, which has an Alpine catchment area and corresponding runoff characteristics, the maximum discharges the most often occur in the summer months (June and July) and in spring (March), the low waters mostly occur in the period between November and January. On the Tisza, which carries the water arriving decisively from the Central Carpathian Mountains and the plateaus or hill lands, the maximum flows occur in spring (between March and May), the law flows in autumn and winter (between September and January).

As regards the maximum discharges, in comparison with the period 1921-1966, in the period 1967-2012 the summer months (June-August) proportion increased and the frequency in November, December and March decreased (Fig.

5). Less yearly maximums occur on the Tisza in March and April and they are more frequent in May, June and February. As regards the minimums on the Duna the frequency in December and January decreased and it increased the cases in autumn (September-November) and those at the end of summer (July-August), while on the Tisza the number of cases in October, January and September decreased and they increased in summer (June-August), as well as the ones at the end of winter-the beginning of spring (February-March).

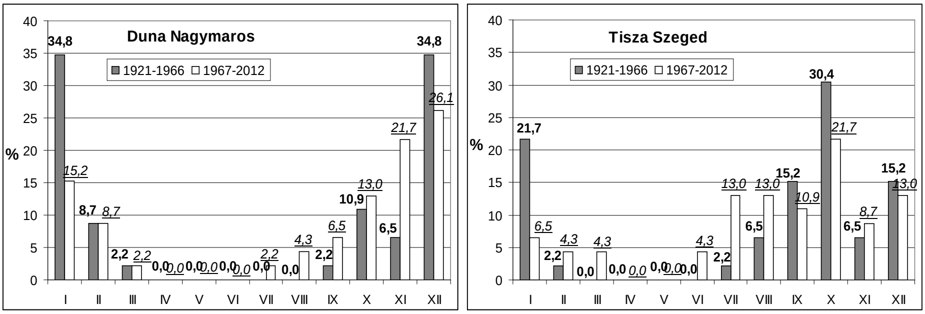

Fig. 5. The monthly frequency of the yearly minimum discharges in two part periods (from 1921 to 1966 and from 1967 to 2012)

6. SUMMARY

In the period 1921-2012 analysed with hydrological, statistical methods, the flow regime indicates a significant difference at the Duna Nagymaros and Tisza Szeged gauging stations, regarding both the medium and the extreme values. So the many years evolution of the surface water supply quantity available in the two river beds is different as well. On the Duna at Nagymaros the many years medium discharge is nearly 3 times higher than the one on the Tisza at Szeged. In the period 1921-2012 at Nagymaros the many years medium discharges decreased, the maximum and minimum discharges increased, however on the Tisza at Szeged all the three discharge characteristics increased.

On the Duna, the proportion between the many years maximum and minimum discharge is lower, than on the Tisza, so the Duna has a less extreme flow regime than the Tisza. There are significant differences between the discharge developments within the year, as on the Duna the high waters typically occur most often in summer (June, July), but the low waters mostly occur in winter (December, January), while on the Tisza in spring (March, April), and in autumn (October).

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