

ACTUAL VALUES OF SATURATED HYDRAULIC CONDUCTIVITY OF CHANNEL BED SILT AND ITS DISTRIBUTION ALONG KOMÁRŇANSKÝ CHANNEL

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This contribution deals with the evaluation of channel bed silt permeability along the Komárňanský channel based on the measurements during the year 2019. Komárňanský channel is the largest one from three great channels of channel network at Žitný ostrov area. The channel bed silt permeability is expressed by parameter of its saturated hydraulic conductivity. This paper describes the current state of channel bed silt distribution along this channel during the year 2019 and simultaneously brings the values of saturated hydraulic conductivity of channel bed silt. The channel bed silts were extracted and obtained by two ways, as a disturbed samples and as an undisturbed samples. The samples were taken in each selected profiles of channel in three layers – top, middle and bottom layer of channel bed silt. The selection of sampling was made in dependency on channel bed silt thickness in the measured profile. The values of channel bed silt saturated hydraulic conductivity from disturbed samples K_d were calculated according to empirical formulas of Bayer-Schweiger and Špaček. The valid values K_d reached from 1.09×10^{-08} – $1.98 \times 10^{-04} \text{ m s}^{-1}$. The values of channel bed silt saturated hydraulic conductivity from undisturbed samples K_u were determined by the laboratory falling head method. The acquired values K_u for Komárňanský channel reached from 3.73×10^{-08} – $2.01 \times 10^{-05} \text{ m s}^{-1}$. The current state of longitudinal distribution of channel bed silt along this channel was demonstrated in the paper graphically and values of saturated hydraulic conductivity were demonstrated numerically.

KEY WORDS: Žitný ostrov channel network, channel bed silt, grain size analysis, silt permeability, saturated hydraulic conductivity

Introduction

The channel network at Žitný ostrov (ŽO) area was built already in the late 19th century with primary aim to drain the wet places of this area. Thereafter its utilization began also to surface irrigation during dry periods and also to groundwater resources regulation in some ŽO localities. ŽO area is a flat plain with only small differences in altitude and that's why the flowing velocities in channels are very low. Just these slow velocities cause the silting up on the bottom of channels. It is very important to observe the development of this channel bed silt aggradation continuously, forasmuch as the channel network is in close interaction with groundwater. The silting up of channel bed by sediments has impact to bed permeability in time and by this way to interact with surrounding groundwater. The permeability is expressed by value of saturated hydraulic conductivity. This parameter can be determined from granularity analysis of extracted bed silt samples. This paper is addressed to results of field measurements along the Komárňanský channel in 2019 with aim to find out the current state of silting up at this channel and the influence of bottom aggradation degree to interaction between channel and its

surrounding groundwater. The values of saturated hydraulic conductivity were determined on the base of two ways of channel bed silt extraction (disturbed and undisturbed channel bed silt samples).

Material and methods

Channel network at the ŽO area is created by several main channels – e.g. channel Gabčíkovo-Topoľníky, Chotárny channel (Aszód), Komárňanský channel, channel Čalovo-Holiare-Kosihy, channel Aszód-Čergov, channel Čergov-Komárno, channel Dudváh and by thus network of smaller channels – see Fig. 1. Our research of channels silting up has been concentrated since 1993 to three main channels of this network: channel Gabčíkovo-Topoľníky, Chotárny channel and Komárňanský channel (KCH). The localization of KCH is shown in more details – see Fig. 2.

Mutual interaction between channel network and groundwater of ŽO is influenced not only by general conditions of groundwater flow at ŽO area, but also by water level regime of its channel network. For this reason, many Slovak researchers were interested in solution of groundwater regime at this specific area

(Kosorin, K. 1997; Burger and Čelková, 2004; Čelková, 2014; Mucha et al., 2006; Štekaurová et al., 2009; Baroková and Šoltész, 2014; etc.).

The regulation of water level in channel network should be able to affect the groundwater level in its surrounding. Channels, manipulating objects and pumping stations as basic elements of channel network enable to control water level in channels and by this way to achieve optimal position of groundwater table mainly during

growing season. But on the other hand, during this season the aquatic vegetation affects flow conditions in channels and also the thickness and structure of channel bed silts significantly influence the interaction between surface water in channel network and groundwater in surrounding area of the ŽO.

Komárňanský channel (KCH) is the largest one of three main channels of ŽO channel network. This channel, primary built for drainage, is now used also for irrigation

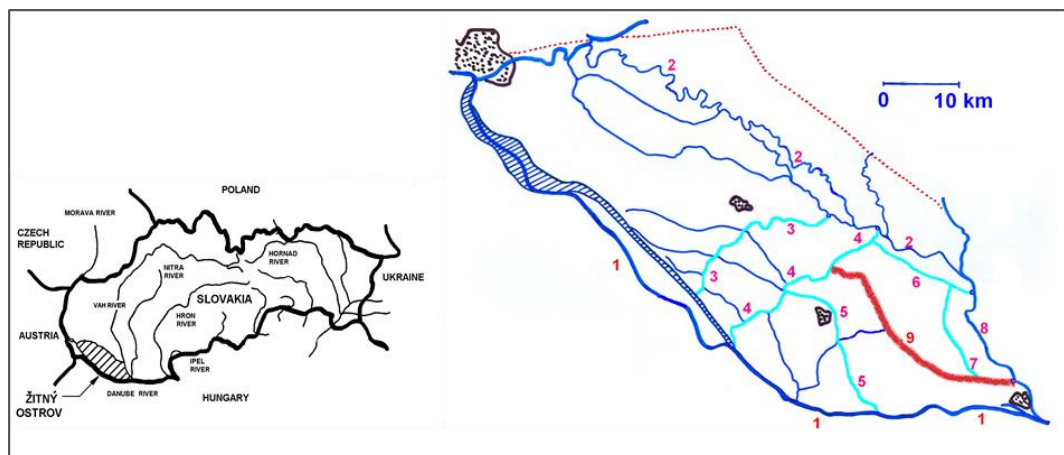


Fig. 1. Schematic map of channel network at ŽO area: left – ŽO situation, right – scheme of channel network: 1 – Danube; 2 – Small Danube; 3 – channel Gabčíkovo-Topoľníky; 4 – Chotárny channel; 5 – channel Čalovo-Holiare-Košihy; 6 – channel Aszód-Čergov; 7 – channel Čergov-Komárno; 8 – channel Dudvák; 9 – **Komárňanský channel**.



Fig. 2. Localization of Komárňanský channel in the territory of channel network at ŽO area.

function. KCH is supplemented from the Váh river over pumping station Komárno – Nová Osada and it connects with Chotárny channel (in rkm 9.1 of Chotárny channel) through a manipulating objects northwest of the Okoč village. The last measured length of the KCH is about 28 km. The channel width during the measurements was in range 10–29 m, the measurements of channel depth registered maximal values up to 2.7 m (according to located cross-section profiles). The values of saturated hydraulic conductivity in aquifers nearby this channel K_{fs} were $0.40\text{--}3.4 \times 10^{-3} \text{ m s}^{-1}$ (Mišigová, 1988).

The measurements of channel bed silt thickness along the KCH were performed in 2019 from the displaceable inflatable dinghy by simple drill hole – see Fig. 3. The measurements were realized along the whole length of the KCH. The distance of cross-section profiles along the channel varied between 1.0–1.5 km. In all channel cross-section profiles there was measured the water depth and channel bed silt thickness with step 1.0–2.0 m along the channel width. Besides of channels silting up also the velocity profiles and discharges were measured during field measurements in 2019. The RiverSurveyor S5/M9 from SONTEK was used – see Fig. 4. The logged files from these measurements confirmed that the velocities in every channel cross-section profile are very low. In some profiles, the channel was overgrown by very dense aquatic vegetation inside the channel (under water level) and also by bank vegetation, so there was impossible to measure velocity profiles and discharges. In 2019 the samples of channel bed silt were taken in

these selected KCH cross-section profiles where the largest channel bed silt thickness was noticed. The extraction of samples was done by equipment (see Fig. 5) which is so-called sediment beaker sampler. There was possible to take undisturbed samples with this equipment and from each whole sample there was extracted a part from top, middle and bottom layer of channel bed silt. After experimental determination of saturated hydraulic conductivity for each layer of sample from one cross-section profile, the sample was broken and changed to disturbed sample. Next, for each disturbed sample it was done the granularity analysis and determined the saturated hydraulic conductivity value.

Saturated hydraulic conductivity of channel bed silt

The values of saturated hydraulic conductivity of channel bed silt was determined from undisturbed samples and also from disturbed samples for the same localities.

The values of saturated hydraulic conductivity from disturbed samples were calculated by empirical formulas coming out from granularity curves. The several empirical relationships for determination of SHC from granularity exist, but their validity is limited and for that reason we should apply them very carefully. In case of disturbed samples sampling we used the relationships by Beyer-Schweiger and Špaček (Špaček, 1987). These relationships are functions of d_{10} – particle diameter in 10% of soil mass [m] and d_{60} – particle diameter in 60% of soil mass [m]. Both of them were determined from



Fig. 3. Equipment for measurement of silt thickness – drill hole probe at channel field measurement.



Fig. 4. Equipment for measurement of the velocity profiles and discharges in the channel – RiverSurveyor S5/M9.

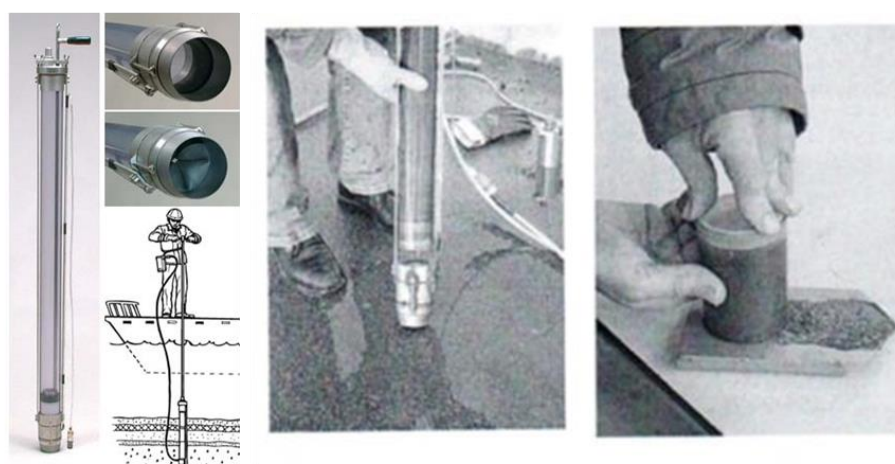


Fig. 5. Measuring equipment for silt samples extraction in 2019 – the Beeker sampler.

granularity curves of extracted samples of channel bed silt. The formulas of Beyer-Schweiger and Špaček (Špaček, 1987) were used for determination of saturated hydraulic conductivity from disturbed samples from KCH – K_d . The equations for Bayer-Schweiger, Špaček I., Špaček II. formulas and for calculation of saturated hydraulic conductivity values have been already cited in previous published papers (e.g. Dulovičová et al., 2016,

Dulovičová et al., 2018). The values of saturated hydraulic conductivity from disturbed samples K_d along the KCH are summarized in Table 1.

In case of undisturbed samples the values of saturated hydraulic conductivity were assessed by falling head method – direct measurement in laboratory. There was used simplified equipment for measuring of saturated hydraulic conductivity from undisturbed samples

(Kutílek, 1978; Rožnovský et al., 2013) – see Fig. 6 (methodology of measurement and calculation described e.g. Šurda et al., 2013; Dulovičová, 2014; Dulovičová et al., 2016; 2018; etc.).

The relation for calculation of average value of saturated hydraulic conductivity K_u according to scheme on Fig. 6 (Šurda et al., 2013) is:

$$K_u = \frac{l}{\Delta t} \ln \frac{h_2}{h_1} \quad (1)$$

where

K_u – is the saturated hydraulic conductivity of undisturbed samples [cm s^{-1}],

l – is a sample height [cm],

h_1, h_2 – variable static head [cm] – see Fig. 6.

The values of saturated hydraulic conductivity from undisturbed samples K_u , extracted from selected cross-section profiles of the KCH, were calculated by the relationship (1) according to scheme on Fig. 6. The values of K_u along the KCH are summarized in Table 2.

Results and discussion

As was mentioned before, flow velocity in the channels

is very slow by low slope condition of whole area of ŽO, which is very flat. The low flow velocity caused the deposition of silt in the channel bottom. The distribution of channel bed silt along the channel depends also on flow conditions in channels junction. We supposed the smaller amounts of the silt deposition in the upstream and downstream parts of KCH (caused manipulating with pumping station) and larger amounts in the middle part. Also we supposed that this increase to be gradual and linear. Our expectations were confirmed partially. The silt thicknesses along KCH during monitored period 2019 showed moderately increasing trend with rising stream log, but in middle part was noticed the decrease of silt thicknesses – see Fig. 7. Globally, the KCH aggradation gradually enlarged with rising stream log (excepting local parts with small amount of deposits) and the channel bed silt thicknesses increased.

Values of saturated hydraulic conductivity from disturbed samples

The value of saturated hydraulic conductivity, as the indicator of channel bed silt permeability, was calculated for disturbed samples by Beyer-Schweiger and Špaček

Table 1. Komárňanský channel – valid values of K_p from disturbed samples of silts in year 2019

Channel		Komárňanský			
Year		2019			
Channel distance [km]	Sampling way	Silt layer	Saturated hydraulic conductivity K_p [m s ⁻¹]		
			<i>Bayer-Schweiger</i>	<i>Špaček I.</i>	<i>Špaček II.</i>
2.0	disturbed sample	top	-	5.33x10 ⁻⁰⁷	-
		middle	-	2.53x10 ⁻⁰⁷	-
		bottom	-	2.60x10 ⁻⁰⁷	-
7.0		top	-	4.10x10 ⁻⁰⁷	1.68x10 ⁻⁰⁶
		middle	-	-	2.92x10 ⁻⁰⁵
		bottom	-	-	2.45x10 ⁻⁰⁵
9.0		top	2.56.10 ⁻⁰⁸	5.00x10 ⁻⁰⁷	-
		middle	-	4.13x10 ⁻⁰⁷	-
		bottom	-	1.01x10 ⁻⁰⁶	-
12.0		top	-	8.07x10 ⁻⁰⁷	-
		middle	-	5.18x10 ⁻⁰⁷	-
		bottom	-	6.37x10 ⁻⁰⁷	-
20.0		top	-	1.19x10 ⁻⁰⁶	-
		middle	-	-	1.24x10 ⁻⁰⁵
		bottom	8.20.10 ⁻⁰⁵	-	1.98x10 ⁻⁰⁴
23.0		top	-	4.44x10 ⁻⁰⁷	-
		middle	-	7.35x10 ⁻⁰⁷	-
		bottom	-	5.70x10 ⁻⁰⁷	-
25.0		top	5.04.10 ⁻⁰⁸	6.94x10 ⁻⁰⁷	-
		middle	-	2.52x10 ⁻⁰⁷	-
		bottom	-	8.66x10 ⁻⁰⁷	-
28.0		top	-	2.40x10 ⁻⁰⁷	-
		middle	1.09.10 ⁻⁰⁸	3.34x10 ⁻⁰⁷	-
		bottom	-	5.06x10 ⁻⁰⁷	-

– unkept conditions of validity for application of Beyer-Schweiger and Špaček formulas

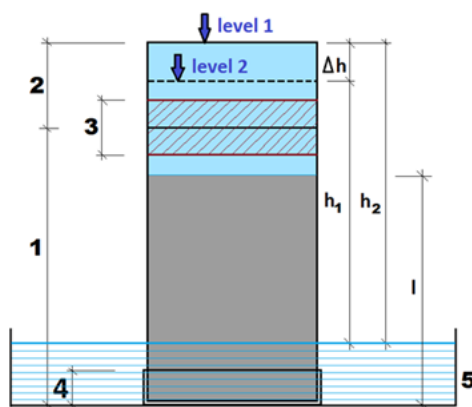


Fig. 6. Simplified equipment for measuring saturated hydraulic conductivity of undisturbed sample: 1 – sampling tube height, 2 – Kopecky's roller, 3 rubber ring, 4 – filter paper and wire strainer, 5 – Petri dish.

Table 2. Komárňanský channel – valid values of K_n from undisturbed samples of silts in year 2019

Channel	Komárňanský		
Year	2019		
Channel distance [km]	Sampling way	Silt layer	Saturated hydraulic conductivity K_n [m s ⁻¹]
2.0	undisturbed sample	top	7.47 x 10 ⁻⁰⁶
		middle	3.84 x 10 ⁻⁰⁶
		bottom	1.34 x 10 ⁻⁰⁷
7.0		top	1.31 x 10 ⁻⁰⁷
		middle	2.54 x 10 ⁻⁰⁶
		bottom	1.32 x 10 ⁻⁰⁶
9.0		top	1.03 x 10 ⁻⁰⁶
		middle	3.76 x 10 ⁻⁰⁷
		bottom	1.05 x 10 ⁻⁰⁶
12.0		top	5.90 x 10 ⁻⁰⁷
		middle	1.06 x 10 ⁻⁰⁷
		bottom	1.24 x 10 ⁻⁰⁶
20.0	top	6.81 x 10 ⁻⁰⁷	
	middle	1.24 x 10 ⁻⁰⁵	
	bottom	2.01 x 10 ⁻⁰⁵	
23.0	top	2.60 x 10 ⁻⁰⁶	
	middle	2.43 x 10 ⁻⁰⁷	
	bottom	2.48 x 10 ⁻⁰⁷	
25.0	top	1.39 x 10 ⁻⁰⁷	
	middle	7.07 x 10 ⁻⁰⁸	
	bottom	1.65 x 10 ⁻⁰⁶	
28.0	top	3.00 x 10 ⁻⁰⁷	
	middle	3.73 x 10 ⁻⁰⁸	
	bottom	5.63 x 10 ⁻⁰⁸	

relationships, which are the function of d_{10} (particle diameter in 10% of soil mass) and d_{60} (particle diameter in 60% of soil mass). The characteristics d_{10} and d_{60} were determined separately for top, middle and bottom layer of extracted samples.

The valid values of channel bed silt saturated hydraulic

conductivity in KCH reached to 1.09×10^{-08} – $1.98 \times 10^{-04} \text{ m s}^{-1}$. In comparison with values of saturated hydraulic conductivity in aquifers nearby this channel K_{fs} (Mišigová, 1988), the values K_d are severalfold lower. Detailed distribution of K_d values along the KCH shows Table 1.

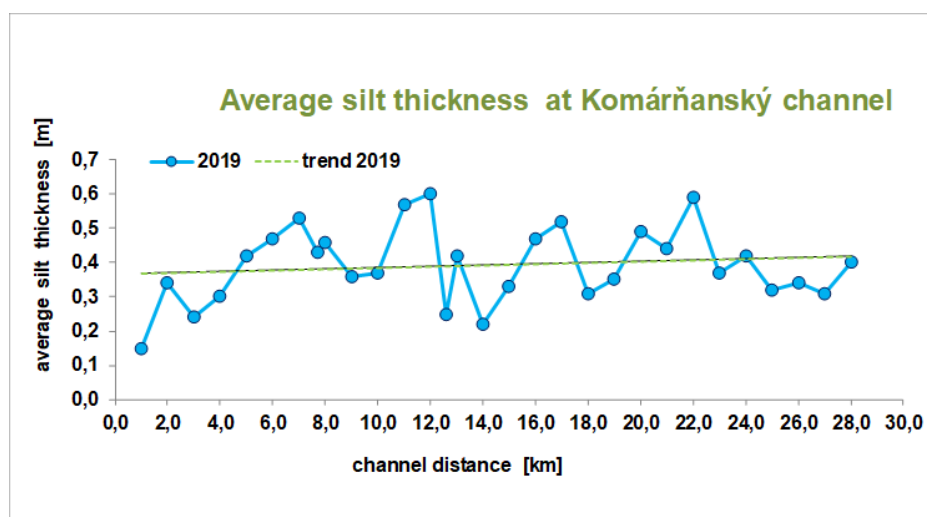


Fig. 7. Average silt thicknesses along Komárňanský channel in 2019.

Values of saturated hydraulic conductivity from undisturbed samples

The values of saturated hydraulic conductivity from undisturbed samples K_u extracted from selected cross-section profiles along the KCH during 2019 were determined by equation (1) in correspondence to scheme on Fig. 6. The valid values of K_u reached to 3.73×10^{-8} – $2.01 \times 10^{-5} \text{ m s}^{-1}$. In comparison with values of saturated hydraulic conductivity in aquifers nearby this channel K_s (Mišigová, 1988), the values of K_u are also severalfold lower. Detailed distribution of K_u values along the KCH shows Table 2.

We also compared the values of saturated hydraulic conductivity obtained from disturbed and undisturbed samples of channel bed silt.

As it is obvious from Table 1, the values of K_d from disturbed samples run into 10^{-8} to 10^{-4} , whereby the values 10^{-7} predominated. Likewise the values of K_u from undisturbed samples run into 10^{-8} to 10^{-5} (Table 2), predominant values were 10^{-7} – 10^{-6} . This fact only partly confirmed our assumption that the values from undisturbed samples K_u will be lower than the values from disturbed samples K_d . The differences between them were practically irrelevant.

At comparison of single layers of channel bed silt, extracted as disturbed samples, we detected that between top, middle and bottom layers were little differences, maximally tenfold.

In case of comparison of undisturbed samples in its single layers the differences between top, middle and bottom layer were tenfold up-to hundredfold.

The interesting results were obtained from mutual comparison of single layers of silt for disturbed and undisturbed samples. As it is obvious from comparison Table 1 and Table 2, along whole KCH the majority of the values K_d and K_u were nearly equal (10^{-7}) in all layers (top, middle, bottom). The assumption of decrease of K_u values opposite K_d values was endorsed only for middle

and bottom layer in km 7.0; for top layer in km 20.0 and for bottom layer in km 28.0; eventually in several cases were K_u values larger than K_d values (tenfold for top and middle layer in km 1.0; tenfold up to hundredfold for top layer in km 9.0; tenfold for bottom layer in km 12.0; tenfold for top layer in km 23.0 and tenfold for bottom layer in km 28.0). This fact is in contradiction with results from measurements in 2016, when obtained K_u values were tenfold lower than K_d values (Dulovičová et al., 2018). The reason of discrepancies between results of K_u and K_d values (the increase of K_u values in 2019 by comparison with 2016) could be caused probably by breaking or elimination of top layer or eventually mutual mixing of all layers during running maintenance processes in the period between 2016 to 2019. In this way could occur the change of channel bed silt permeability expressed by tenfold up to hundredfold different values of channel bed silt saturated hydraulic conductivity.

Conclusion

This paper deals with the evaluation of bed silt permeability along the Komárňanský channel (KCH) on base of field measurements performed during the year 2019. The channel bed silt permeability and the thickness of bed silt determine the rate of mutual interaction between surface water of KCH and nearby groundwater in its surroundings. For this reason it is important to know actual state of channel bed aggradation. The permeability of channel bed silt is expressed by its saturated hydraulic conductivity.

According to results of distribution of average bed silt thickness along the KCH from 2019 it is visible that silting up of this channel has been changed, it gently increased with ascendant stream log, but in middle part there was noticed the local and also global decrease of silt thicknesses – see Fig. 7.

The values of saturated hydraulic conductivity of channel bed silt were determined by two ways: as channel bed silt

extracted and obtained as disturbed samples and as undisturbed samples from top, middle and bottom layer of silt. From disturbed samples the values of saturated hydraulic conductivity of channel bed silt were calculated according to Bayer-Schweiger and Špaček formulas and they are presented in Table 1, the valid values K_d reach from $1.09 \times 10^{-08} - 1.98 \times 10^{-04} \text{ m s}^{-1}$. From undisturbed samples of channel bed silt there were determined values K_u by falling head method and they are summarized in Table 2. The values K_u reached values from $3.73 \times 10^{-08} - 2.01 \times 10^{-05} \text{ m s}^{-1}$.

Some discrepancies in distribution and values of saturated hydraulic conductivity obtained in 2019 and from previous study period exist. For this reason, it is necessary to put these results under the more detailed analysis in the next step in the future.

As it was mentioned, the aggradation along KCH enlarged in 2019, the channel bed silt thicknesses increased. Because the mutual interaction between surface water in channel and groundwater in its surroundings depends on channel bed permeability, which is mainly determined by the channel bed silt thickness and permeability, it is necessary to know these parameters for correct evaluation of the mutual exchange of water amounts between surface water in channel and groundwater in its surroundings. All obtained information about actual state of silting up of KCH, supplemented by values of saturated hydraulic conductivity channel bed silt, will be helpful for numerical simulation models, also for any way of regulation of groundwater level in surroundings of this channel and water source management at ŽO area.

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