INVESTIGATION OF DIRECT AND INDIRECT SUSPENDED SEDIMENT MEASURING METHODS

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Abstract
The study describes the basic forms of river sediment transport. The author then presented the sampling methods used in domestic practice and their disadvantages. In the last part of the paper, a new development of sediment monitoring based on novel measurement technologies was presented, which can help to better understand the spatial and temporal variations of sediment transport in the Tisza.

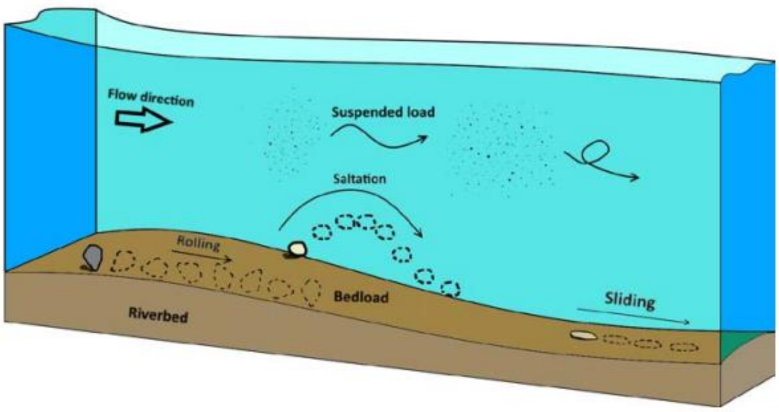
Keywords:
Tisza, suspended sediment monitoring, turbidity probe, indirect measurement methods, direct measurement methods

INTRODUCTION

The morphological changes in riverbeds are mainly influenced by the transport of sediment spatial and temporal distribution of sediment transport. If the sediment transport capacity (characterised by bed shear- stress or turbulence) is so reduced that the flow can no longer transport some of the solid particles in the water, then sediment deposition occurs. Higher bed shear-stress and turbulence bed erosion occurs.

Knowledge of river sediment transport conditions and sediment balance is essential for river management experts. Sediment balance is very important for understanding changes in riverine ecosystems, channel morphology, and related habitat resources. That is why it is necessary to know if a certain reach of a river is in a state of sediment equilibrium, accumulation, or deficit (Griffiths and David, 2018). In the case that there are gauging stations along the river where regular sediment monitoring takes place, the changes of the sediment balance over time or the influence of tributaries and floodplains can be observed. It makespossible to investigate sediment transport processes, deposition, and erosion between the stations.

The sediment transport can be generally divided as suspended load and bedload, depending on the size of the bed material particles and the flow conditions (Van Rijn 1984). While the suspended load contains suspended particles in motion, in the bedload transport, the particles are rolling, sliding, or saltating along the bed. The most important parameters and characteristics of the suspended sediment transport are suspended sediment concentration (SSC), suspended sediment load (SSL), and particle size distribution, along with characteristic particle sizes.



1. Fig. Transport modes of sediment int he rivers (Habersack et al, 2019)

CURRENTLY APPLIED DIRECT SAMPLING METHODS OF SUSPENDED LOAD ON TISZA RIVER

In case of Tisza the currently applied methods tend to be expensive, difficult, labor intensive, and, under some conditions, e.g., during high floods, hazardous. In Hungary, direct sampling is still an integral part of the sediment monitoring standardization, and it prescribes sampling by a bottle sampler or with a pump. (*regulated by ME-10-231-20:2009 (Measurement of suspended sediment in surface waters with a pump water sampler, provided by KÖTIVIZIG*)

During pump sampling, the sample is brought to the surface (on the Tisza, aboard a measuring ship anchored in the vertical) with a pump. In Hungarian engineering practice, the end of the pump suction tube is lowered into the sampling point using a suitable weight, and the sample of the required volume is sucked up. The disadvantage of the pumping method is that if the sampling velocity does not match the water velocity at the point, the sediment concentration of the sample will not, either. Depending on the relative sampling rate (sampling rate/water velocity), the difference in concentration can be reached +60%. (Garcia, 2008)

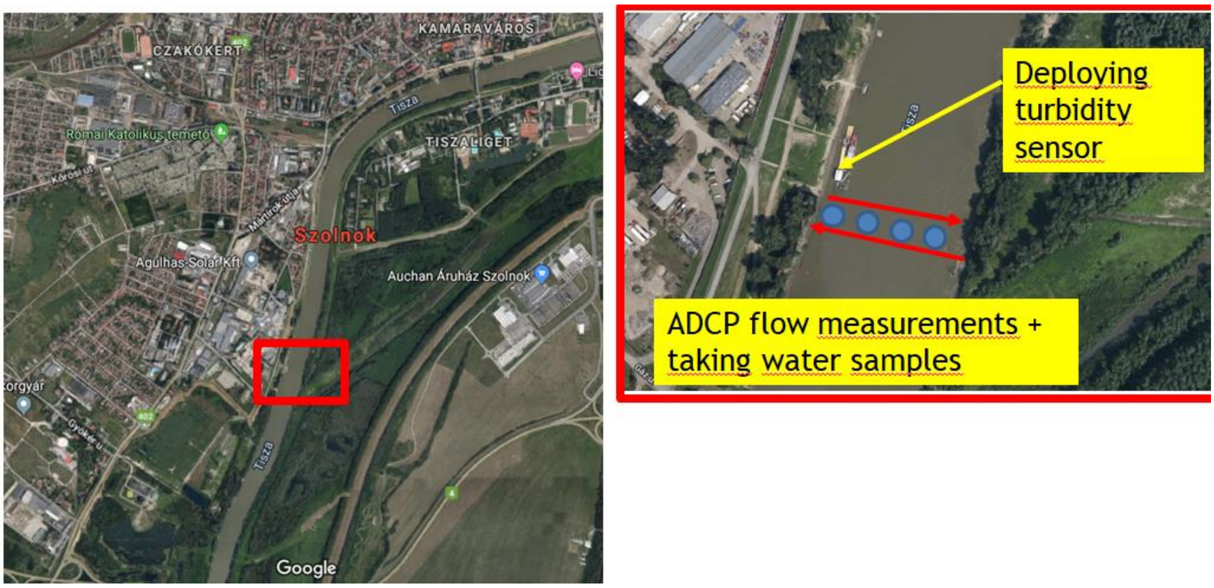
Direct sampling methods can be further subdivided according to the number of sampling verticals, and the literature distinguishes between single- and multi-vertical methods. The location of the verticals in the case of the single-vertical method is determined based on different technical considerations (in the middle, at the maximum depth). The Hungarian standard on suspended sediment sampling provides for a multi-vertical method where the lamellae are of equal width, but the average sample for a given vertical is to be prepared by taking 1 liter of sample in the vertical at each of the 10 points of different depths, evenly distributed, and then pouring these samples together into one canister to form the vertical average sample with a volume of 10 liter. In the case of the Tisza, the standard requires for five sampling verticals.

LONG –TERM MEASUREMENT PLAN FOR IMPLEMENTING SURROGATE INDIRECT SAMPLING METHODS FOR TISZA RIVER AT SZOLNOK

According to the problems and challenges described previoussly, the implementation of a completely new approach to sediment monitoring has been identified. The aim of the present study is to present the plan of the application an alternative sediment measurement method to evaluate the sediment transport of the Tisza River, Hungary. The Tisza transports large amount of suspended sediment; thus, the spatio-temporal description of its sediment transport is a fundamental research task.

Study area

A typical section of the Middle -Tisza (section below the Zagyva confluence at Szolnok) *(Fig. 2)* was defined as the study area for the research. The section is characterized by a moderate slope (2-3 cm/km). There is a gauging station in Szolnok (334.6 fluvial km; height: 78.78 m.a. baltic sea level), with a time series of water level for more than a hundred years, and with regular discharge and sediment measurements. Here, the flow velocity is 0.2-0.4 m/s at low water, 0.5-0.8 m/s at medium water, and 1.4-1.5 m/s in case of floods. The largest water level difference between the lowest and highest stages is more than 13,0 m (lowest stage: –291 cm; highest stage: 1041 cm). The lowest measured discharge is 68 m^3/s, while the highest is 2640 m^3/s; thus, there is an almost 40x difference between discharges. The planned suspended sediment monitoring station will be placed on the floating platform located near to 334.0 fluvial km. According to the data of Hydrographical yearbooks *(provided by KÖTIVIZIG)* the annual average suspended sediment load (*SSL*) is about 11 530 ton/year. The annual amount of bedload is on average less than 1% of the amount of suspended sediment.



2. Fig.: Study area at Szolnok. The yellow dot represents direct water sampling points (at ca. 334.0 fluvial km)

Intended methods and materials

Laboratory analyses

In order to provide *reference suspended sediment concentration* values for the calibration of the indirect methods, all the collected water samples will be analysed in the laboratory of Middle Tisza District Water Directorate, applying also the filtration method *(Fig.3)*. A brief description of filtration method:

First, the water samples are filtered with a vacuum filter unit, through a membrane filter with a 0.45 µm pore size, so that the suspended substances in the water remained on the surface of the filter paper. The individually numbered filter papers are dried in an oven at 105 °C until their mass became constant. Then, their mass (m_1) are weighed (on analytical scale, accuracy: ±0.1 mg). The volumes of the water samples are measured (V_m , in ml), and then they were filtered through a membrane filter, then the filter papers were dried again until their weight became constant (at 105°C), and then their weight (m_2) was measured again. The suspended matter concentration (SSC) of a water sample are calculated using the following formula:

$$SSC\left(^{mg}/_{l}\right) = \frac{m_{2}-m_{1}}{V_m}$$

3. Fig. Devices of filtration methods (author's photos)

(on the left: numbered filter papers with 0,45 µm pore size; in the middle: vacuum pump; on the right: analytical scale)

Optical devices

We have also planned to use optical instruments e.g.: LISST-Portable|XR *(Fig.4)* analyses low-angle laser scattering. The laser light emitted by the instrument passes through of the sample, then reaches the converging lens, which transmits the scattered light to the concentric detector rings. The scattering area of the detected light determines the particle sizes in the sample, so each detector ring receives different amounts of light and different particle sizes are detected by them. Knowing the probability density of the 44 particle size ranges, the volumetric PSD can be plotted. (Sequoia Inc. 2018). This is very useful, as determining the PSD is rather difficult and time-consuming otherwise. The measurementrange of the LISST-Portable|XR is 10–1900 mg/L (depending on the particle size) with a ± 20% accuracy. The technical limitations of laser difraction have been wide range tested. (Czuba et al., 2015)

4. Fig. LISST-Portable|XR (Sequoia Inc. 2018)

Indirect methods, e.g., turbidity measurement can also determine the sediment concentration of rivers. (Boss et al. 2018) Turbidity expresses the reduced transparency of water, which is caused by the particles in the water scattering and absorbing light rays passing through the water. The turbidity meters used today are based on the laws of nephelometry. The size, colour, refractive index and shape of the particles influence the amount of scattering. During nephelometric measurements, the 90° scattering of light rays is measured in the visible or infrared range. Optical reflectance measurement (OBS-Optical backscatter sensors) instruments measure light rays scattered at 140-165° in the infrared range (Sutherland et al., 2000). We have planned to continous turbidity measurements with OTT HL-7 probe *(Fig.5)* near to bank of river to make calibration relationship between turbidity and near-bank sediment concentration.

5. Fig. HYDROLAB 7 water quality probe (OTT, 2019)

Acoustic devices

Instruments based on the acoustic theory have been widely used as surrogate techniques of suspended sediment monitoring. (Habersack et al., 2019) The estimation of SSC from ADCP backscatter is an increasingly common procedure. The main idea behind the estimation of suspended sediment concentration from ADCP measurements is that the backscattered signal strength and the suspended sediment concentration is correlated. The backscattered echo strength is a function of the amount of suspended matter in the water column. After determining the suspended sediment concentration of the water samples, the regression analysis can be done, with which the relationship between backscattered signal and sediment concentration can be formed. Using this relationship, the total cross-sectional distribution of suspended sediment concentration can be approximated from the ADCP measurements (Baranya and Józsa 2010; 2013).

SUMMMARY AND CONCLUSIONS

Suspended sediment transport in the Tisza River is significant and is related to the large accumulation of sediment in the floodplains since the river was regulated. The results of the sediment measurement methods used in domestic engineering practice are questionable, and the measurements are difficult and time-consuming.

In this study have presented a methodology based on international recommendations, which proposes an up-to –date monitoring system that is in line with the professional and technical standards of the time. This proposal provides a basis for the long-term development of sediment monitoring in case of Tisza river. In addition, the expected research results will help experts understand the spatial and temporal variations of sediment transport of Tisza River.

REFERENCES

Baranya S., Józsa J. (2010) ADCP alkalmazása lebegtetett hordalék-koncentráció becslésére. *Hidrógiai Közlöny* 90. évf. 3. szám, pp. 17-22.

Baranya, S.; Józsa, J. (2013) Estimation of suspended sediment concentrations with ADCP in Danube river. *J. Hydrol. Hydromech.* , 61, 232–240

Boss E, Sherwood CR, Hill P, Milligan T. (2018). Advantages and Limitations to the Use of Optical Measurements to Study Sediment Properties. *Applied Sciences.* 8(12):2692

Czuba, J.A.; Straub, T.D.; Curran, C.A.; Landers, M.N.; Domanski, M.M. (2015) Comparison of fluvial suspended-sediment concentrations and particle-size distributions measured with in-stream laser diffraction and in physical samples. *Water Resour. Res*., 51, 320–340

Griffiths, R.E.; David, J.T. (2017) Importance of measuring discharge and sediment transport in lesser tributaries when closing sediment budgets. Geomorphology 269, 59–73.

Habersack, H., Baranya, S., Holubova, K., Vartolomei, F., Skiba, H., Schwarz, U., Krapesch, M., Gmeiner, Ph., Haimann, M. (2019.) Danube Sediment Management Guidance. Output 6.1 of the Interreg Danube Transnational Project DanubeSediment co-funded by the European Commission, Vienna.

OTT Hydromet (2019) : HL Series Sensors User manual; Edition 4.

Sequoia Inc. (2018). LISST-Portable|XR Manual Version 1.3.

Sutherland, T., Lane, P., Amos, C., Downing, J., (2000). The calibration of optical backscatter sensors for suspended sediment of varying darkness levels. *Marine Geology*, 162, 587-597.

Van Rijn, L.C. (1984*)* Sediment transport, part I: Bed load transport. *J. Hydraul. Eng*. 110, 1431–1456.