Sediment sampling in large rivers
DanubeSediment project

Introduction of applied sediment monitoring methods along the Danube

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Project methodology

WP3 - Sediment data collection
- Sediment database set up within WP3 will be thoroughly analyzed in WP4

WP4 - Danube Sediment Balance
- Based on the sediment continuity related issues revealed in WP4, engineering measures will be worked out

WP5 - Impacts and measures

WP6 - Synthesis: Danube Sediment Management Guidance
- Sediment monitoring best practices
- Comprehensive information on sediment balance
- Catalogue of best practices of measures
 WP3: Sediment Data Collection

Objectives

- Reveal all available sediment data for the Danube and the major selected tributaries at the confluence
- Permanent interaction with the data owner stakeholders (water directorates, private companies, Project Partners)
- Limited sediment transport monitoring at short reaches with significant data gaps
- Comparative analysis and intercalibration of different sediment monitoring techniques
- Recommendations for the good practices of sediment monitoring techniques
- Training of sediment experts on an international workshop
Transport modes of sediments in rivers
Sediment monitoring system along the Danube and at the most important tributaries

Collection of metadata

- Web based questionnaire
Suspended sediment monitoring stations along the Danube and at the most important tributaries (closest to the confluence)

**SUSPENDED SEDIMENT MONITORING STATIONS**

- **SS monitoring stations**: 65
- **BL monitoring stations**: 25

Legend:
- **Suspended sediment monitoring stations**
  - Danube
  - Tributary

- **Cities**
  - 100,000 - 250,000 inhabitants
  - 250,000 - 1,000,000 inhabitants
  - > 1,000,000 inhabitants

National Borders

Map 1

http://www.interreg-danube.eu/approved-projects/danubesediment

This map was produced in the frame of the EU funded project DanubeSediment, and is based on national information provided by Contracting Parties (AT, BG, DE, HR, HU, RO, RS, SK).

Budapest, April 2018
Suspended sediment monitoring stations along the Danube and at the most important tributaries (closest to the confluence)

**SUSPENDED SEDIMENT SAMPLING FREQUENCY**

Legend

Suspended sediment sampling frequency

- **Danube**
- **Tributaries**
- **Danube River Basin**

- 4 times per hour
- 1 times per day
- cca. 2 times per week
- 1 times per month
- 5 times per month
- 36 times per year
- 9 times per year
- 5 times per year

Cities

- 100,000 - 250,000 inhabitants
- 250,000 - 1,000,000 inhabitants
- > 1,000,000 inhabitants

National Borders

0 50 100 200 km

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Budapest, April 2018
Suspended sediment monitoring in Germany

- Responsible institute: Bavarian Environment Agency (LfU), Bavarian Hydrological Service (GKD), Federal Waterways and Shipping Administration (WSV)
- Automatized monitoring using Optical Backscatter Sensors (OBS), physical sampling (bottle)
- Sampling frequency: 15 min
- Nr. of stations: 9 (2 trib.)
Suspended sediment monitoring in Germany

- Calibration of OBS – point sampling at the sensor

- Multipoint sampling and
- Acoustic profiling:
  - StreamPro ADCP + ViSea
- SSC analysis method: filtering
Suspended sediment monitoring in Austria

- Responsible institute: ViaDonau, Verbund Hydro Power
- Automatized monitoring using Optical Backscatter Sensors (OBS), pump sampling, automatized bottle sampling
- Sampling frequency: 15 min
- Nr. of stations: 11 (4 trib.)
Suspended sediment monitoring in Austria

- Estimation of sediment load (Habersack et al., 2013):

Turbidity

Concentration close to the sensor

Mean concentration

Suspended sediment transport

Suspended sediment load

Probe characteristic $s_k = a_s s_s$

Probe factor $k_s = s_k / s_s$

Cross-sectional characteristic $s_m = a_s s_k$

Discharge $Q_s = s_m Q$

Time $V_s = \int_{t_1}^{t_2} Q_s(t) \, dt$

Suspended sediments vary in space and time
Suspended sediment monitoring in Austria

- Cross-sectional calibration – multipoint sampling
Suspended sediment monitoring in Austria

- Laboratory analysis of water samples
- SSC → vacuum filtration (0.45 μm filter), drying (2 hours on 105°C), weighing
- PSD → sieving instrument and sedimentation instrument
Suspended sediment monitoring in Slovakia

- Responsible institute: SHMU, VUVH
- Typical frequency: 3 to 20 times/week
- Depth-integrated sampling at representative verticals
- Nr. of stations: 5 (1 trib.)

- SSC → filtration of 0.2 l (0.45 μm filter), drying (24 hours on 105° C), weighing
Suspended sediment monitoring in Hungary

- Expeditionary multipoint measurements
- Typical frequency: 5 times/year
- 7 verticals, 10 points/vertical, 1 liter/point using pump
- 10x1 liter samples are integrated → sedimentation → extraction of 9 liters → remaining 1 liter is analysed → drying, weighing
- PSD → sedimentation instrument
- Nr. of stations: 7 (1 trib.)

\[ C_k = \frac{G_s}{\sum q_i} \]

\[ G_s = \sum_{i=1}^{7} (q_i \cdot \bar{C}_i) \]
Suspended sediment monitoring in Hungary

- Pump sampler

- Estimation of SSL using sediment rating curves and actual discharge
Suspended sediment monitoring in Croatia

• Daily physical sampling in one point at the water surface using bucket sampler → filtration (0.45 μm filter) → filters to laboratory, drying (on 105°C), weighing
• Multipoint measurements 6 times/year with pump
• Nr. of stations: 1 trib.
Suspended sediment monitoring in Serbia

- Daily physical sampling in one point at the water surface using bucket sampler (10 liters) → filtration (0.45 μm filter) → filters to laboratory, drying (on 105° C), weighing
- Multipoint measurements 1-3 times/year with vacuum bathometer in 7-10 verticals, 5 points/vertical, ~40 liter sample/point
- Estimation of SSL → Correlation between surface concentration and mean concentration along the cross-section
- Sedimentation of samples for days → 1-1.5 liter of concentrated sample is extracted → repeated settling for a day → 0.1 liter of concentrated sample is extracted → drying, weighing
- Nr. of stations: 7 (3 trib.)
Suspended sediment monitoring in Serbia

- Daily physical sampling
- Multipoint measurements 4-6 times/year with bathometer in 5-9 verticals
- Correction of point samples with cross-section calibration → daily sediment discharge
Suspended sediment monitoring in Bulgaria

- Daily physical sampling with bottle sampler at the river bank
- Mean concentration in the cross-section is assumed to be the measured one at the river bank → daily sediment discharge
- Nr. of stations: 6 (2 trib.)
Suspended sediment monitoring in Romania

- Daily physical sampling with bottle sampler at the river bank
- Multipoint measurements 4-6 times/year with bathometer in 5-9 verticals
- SSC is determined using a portable turbidity sensor
- Nr. of stations: 19 (5 trib.)
Suspended sediment monitoring stations along the Danube and at the most important tributaries (closest to the confluence)

SUSPENDED SEDIMENT ANALYSIS METHODS

Legend

Suspended sediment analysis methods:
- Filtration
- Evaporation
- Turbidity meter

Cities:
- 100,000 - 250,000 inhabitants
- 250,000 - 1,000,000 inhabitants
- > 1,000,000 inhabitants

National Borders

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Budapest, April 2018

http://www.interreg-danube.eu/approved-projects/danube Sediment
Suspended sediment monitoring stations along the Danube and at the most important tributaries (closest to the confluence)

SUSPENDED SEDIMENT MONITORING STATIONS

65 SS monitoring stations
25 BL monitoring stations

Legend

- Suspended sediment monitoring stations
  - Danube
  - Tributary

- Cities
  - 100,000 - 250,000 inhabitants
  - 250,000 - 1,000,000 inhabitants
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- Danube River Basin

Map 1

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Budapest, April 2018
Bedload monitoring stations along the Danube and at the most important tributaries (closest to the confluence)

BEDLOAD MONITORING STATIONS

Legend

Bedload monitoring stations
- Danube
- Tributary
- Danube River Basin

Cities
- 100,000 - 250,000 inhabitants
- 250,000 - 1,000,000 inhabitants
- > 1,000,000 inhabitants

National Borders

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Budapest, April 2018

http://www.interreg-danube.eu/approved-projects/danubesediment
Bedload monitoring

- Germany: expeditionary monitoring campaigns at 9 sites
  - BfG sampler
  - Sampling from ship
  - Rating curves

- Austria (1 station):
  - BfG sampler (monitoring at Bad-Deutsch Altenburg)
  - Mesh size: 1 mm
  - Sampling from bridge or from ship
  - 8-15 verticals, 3x5 minute long samplings
  - 3 times/year
  - Drying, sieving
Bedload monitoring

• **Slovakia (2+1 stations):**
  • intensive measurement campaigns in 1997-1998 and 2002-2003
  • Swiss-type sampler, 5-6 verticals
  • 2-5 min long samplings
  • Drying, sieving of the samples
  • Rating curves have been set up
Bedload monitoring

- Hungary (1 station):
  - continuous monitoring since 1998 at Vámosszabadi (Medvedov)
  - 4-6 times/year using the modified Károlyi-sampler at 7 verticals
  - 15 min long samplings
  - Drying, sieving of samples
Bedload monitoring

• Romania (11 stations):
  • 4-6 times/year at 11 monitoring stations, 5-9 verticals
  • ~10 min long samplings
  • Drying, sieving (0.063-50 mm)
Longitudinal variation of long-term (1986-2016) mean annual suspended sediment load along the Danube River

>60% decrease!
Thank you for your attention!

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WP3: Sediment Data Collection

Activity 3.3 – Assessment of sediment data

Influence of floods on SS transport

- 20M tons mobilized in AT (mean annual around 5Mt)
WP3: Sediment Data Collection

Activity 3.3 – Assessment of sediment data

Longitudinal variation of characteristic sediment grain sizes

**Diagram:**
- Longitudinal variation of SS and BL characteristic grain sizes
- Missing fraction ~ 0.1-2 mm
WP3: Sediment Data Collection

Activity 3.3 – Assessment of sediment data

Bedload transport
WP3: Sediment Data Collection

Activity 3.2 – Comparative analysis

Good practices in SS monitoring

Methodology

<table>
<thead>
<tr>
<th>Turbidity</th>
<th>Probe characteristic $s_k = a \cdot s_s$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Probe factor $k_s = s_k / s_s$</td>
</tr>
<tr>
<td></td>
<td>Cross-sectional characteristic $s_m = a \cdot s_k$</td>
</tr>
<tr>
<td>Con. close to sensor</td>
<td>Cross-sectional calibration</td>
</tr>
<tr>
<td>Mean conc.</td>
<td>Load $Q_s = s_m \cdot Q$</td>
</tr>
<tr>
<td>Susp. sediment load</td>
<td>Time $V_s = \int_{t_1}^{t_2} Q_s(t) , dt$</td>
</tr>
<tr>
<td>Annual Susp. sediment load</td>
<td></td>
</tr>
</tbody>
</table>
WP3: Sediment Data Collection

Activity 3.2 – Comparative analysis

Good practices in SS monitoring

Sensor calibration

- Turbidity
- Concentration close to the sensor
- Mean concentration
- Suspended sediment load
- Annual Suspended sediment load
WP3: Sediment Data Collection

Activity 3.2 – Comparative analysis

Good practices in SS monitoring

Cross-sectional calibration (isokinetic sampling!)

- Turbidity
- Concentration close to the sensor
- Mean concentration
- Suspended sediment load
- Annual Suspended sediment load

Expeditionary measurements

Haimann et al. (2014)
WP3: Sediment Data Collection

Activity 3.2 – Comparative analysis

Good practices in SS monitoring

Temporal variation of SS load

- Turbidity
- Concentration close to the sensor
- Mean concentration
- Suspended sediment load

![Graph showing temporal variation of SS load](chart.png)
WP3: Sediment Data Collection

Activity 3.2 – Comparative analysis

Good practices in SS monitoring

Protocols
WP3: Sediment Data Collection

Activity 3.2 – Comparative analysis

Good practices in SS monitoring

*Laboratory analysis after BMLFUW (2008, 2017)*

- **Main steps:**
  - Drying of membrane filter (of 0.45 μm pores) at 105°C until constant weight, after the drying the filter is placed in a desiccator, to let the filter cool down.
  - Mass of the plate and filter is measured ($m_a$).
  - Membrane filter is placed into the filtering device.
  - Sample is poured into the filtering device and its volume is measured precisely ($V_p$).
  - After filtering, the membrane filter is dried at 105°C until constant weight, after the drying the filter is placed in a desiccator, to let the filter cool down.
  - Plate and membrane filter is weighted again ($m_b$).
  - Dry matter content is: $m_T = m_b - m_a$ [mg].
  - SSC = $m_T / V_p$ [mg/l].

WP3: Sediment Data Collection

Activity 3.2 – Comparative analysis

Good practices in BL monitoring

Methodology

- Sample weight and sampling time
- Transport rate for each sample
- Transport rate for a vertical
- Cross-sectional bedload transport
- Bedload yield

Integrate over time:
Bed load – discharge relation (rating curve)
And Discharge

Calibration coefficient
Sampler width
Average samples of one vertical
Integrate over the active width
Integrate over time:
Bed load – discharge relation (rating curve)
And Discharge