Pressures and impacts related to quantity and quality aspects of sediments

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International Commission for the Protection of the Danube River

Internationale Kommission zum Schutz der Donau

Annex 8 of the DRBM Plan

Deutschland //// Österreich //// Česká republika //// Slovensko //// Magyarország //// Slovenija //// Hrvatska //// Bosna i Hercegovina //// Србија //// Crna Gora //// România //// България //// Moldova //// Україна

1. General overview

Sediments are particulate inorganic materials transported by water from upstream sources to the downstream areas of deposition. Sediments are produced by the weathering and erosion of mountains/rocks and soils and are carried in rivers as suspended load or as bed-load. Sedimentation and remobilisation of material transported mainly in alluvial watercourses take place on the banks and beds of rivers, and in the floodplains usually during floods. In general, there is erosion in the upstream parts of the catchment; transfer, deposition and remobilisation in the middle parts and in the lower sections of most rivers, the majority of the remaining sediment transported from inland to sea is deposited within the estuary and in the coastal zone. Torrents and reservoirs of hydropower plants act as human-made sediment traps. Damming affects the hydrology and morphology of the river upstream and especially downstream, mainly by interrupting the continuity of sediment transport. The relatively clear water leaving reservoirs and the limited sediment supply cause the incision of the river bed into the terrain.

Sediment acts as a potential sink for many hazardous chemicals. In river reaches with a long and undisturbed record of sedimentation, sediment cores may reflect the history of pollution in a given river basin. Where water quality is improving, the accumulated pollutants may still be present attached to sediment grains hidden at the bottom of rivers, behind dams, in lakes, estuaries and seas, as well as on floodplains. This annex provides a brief summary overview of the current knowledge on pressures and impacts related to sediment quantity and quality in the Danube River Basin (DRB).

2. Sediment quantity

2.1. Sediment balance

At present the sediment balance of most of the large rivers within the Danube Basin can be characterised as disturbed or severely altered. Morphological changes due to river engineering works, torrent control, hydropower development and dredging, as well as the reduction of adjacent floodplains by nearly 90%, are the most significant impacts during the last 150 years.

<u>Bed-load material</u>
The hydropower plants in the upper Danube catchment trap almost 80-90% of the sediment bed-load. For example, significant reduction of bed-load material was recorded on the Inn: from approx. 540,000 t/yr close to zero[1]. Additionally, torrent control reduces erosion and transfer of material so that a deficit of bed-load exists at the majority of the free-flowing river sections in the Danube catchment. On the other hand, there exists a surplus of material in the reservoirs of hydropower plants. This diverting development is still ongoing.

The middle Danube is characterised by the transition of the river from a gravel river into a sand river (due to a decreasing slope). Downstream of the Gabcikovo Dam, the fine gravel load (7-10 mm) currently amounts to approx. 250,000 m³/yr, while near Budapest the amount of transported bed-load declines considerably to approx. 50,000 m³/yr. In the lower Danube, the suspended load dominates the overall sediment transport.

Suspended sediments

For the suspended load, the retention in the upper catchment by river barrages or any kind of impoundment is not as efficient as for the bed-load. In particular, during floods huge amounts of fine sediment are transported from the upper to the lower catchment. During an extreme (200 years) flood event in August 2005 on the Inn River at Innsbruck, the 5-day assessment showed that about 1.74 million tonnes of particulate matter in suspension had been transported across the gauging section. This was about twice as much as the annual sediment load reported for the same site for the whole year of 2004 (0.82 million tonnes). The comparison of both values clearly reveals the necessity for a continuous and more accurate monitoring of the transport of suspended sediments. At present the torrent control works and impoundments on the upper catchments in the Danube River Basin retain about 1/3 of the suspended load.. In impounded sections during much shorter periods of time (mainly during floods), large quantities of sediments are remobilised and deposited e.g. in the inundated floodplains.

In the lower Danube, transport of the suspended load currently reaches only 30% of the original amount recorded before the construction of the Iron Gate Dams. Moreover, many tributaries of the lower Danube deliver only a very small amount of sediment in comparison with that measured before the construction of dams and reservoirs in their upper stretches. In the Danube Delta region, the annual natural sediment load decreased from 53 million to 18 million t/yr due to hydro-technical works in the entire DRB.

2.2. Erosion & deposition

Downstream of torrent control works and hydropower plants, river bed degradation is very intensive due to sediment deficit and is enhanced by river regulation (increase of slope, decrease of channel width, suppression of bank erosion).

In Bavaria, the Danube reach from Straubing to Vilshofen has an overall incision tendency of 1.5 cm/yr. Along the Austrian Danube, in the free-flowing stretch within the Wachau, a slight deepening of 0-1 cm/yr is observed, and the stretch downstream from Vienna has a degradation of 2-4 cm/yr. Along the Hungarian-Slovakian border, the channel incision downstream of the Gabcikovo power plant is 2-3 cm/yr; however it reduces downstream of Komárno to 1-2 cm/yr (including the impact of the Danube bend gorge, which is a regional erosion base). The overall riverbed incision in Hungary is estimated to be about 1-3 cm/yr. For the Serbian reach further downstream to the Iron Gate backwater (near the Tisza confluence) there is no clear evidence of channel incision. Downstream of the Iron Gate Dams, the rate of degradation along the Romanian-Bulgarian Danube reaches an average value of 2-3 cm/yr.

Upstream of dams in reservoirs or impounded sections, the reduction of the sediment transport capacity of water results in sediment deposition. This retained sediment has often to be dredged in order to maintain the river depth for navigation, standard reservoir operation, as well as to limit the height of the water level in case of floods. However, the excavated material should be reinserted into the river to maintain the overall sediment balance. Downstream of dams, the loss of the sediment sometimes requires an artificial supply of bed-load material or other engineering measures to stabilise the riverbed and prevent incision.

2.3. Dredging

The extraction of sediment is mostly necessitated by navigation (minimum water depth), flood protection purposes, reservoir management and torrent control. The major dredging user groups include:

- Waterway transport maintenance dredging;
- Commercial extraction, construction sector;
- Channel maintenance for flood protection;
- Impoundment clearing for hydropower plants;
- Fish farming.

Dredging is very common along the entire Danube River. In the upper Danube countries, commercial dredging is not allowed anymore and the situation in many new EU countries is changing towards more limitations and stronger requirements required by environmental impact studies. However, the total amount of maintenance dredging is still considerable and the amounts dredged in the past often cannot be compensated for by the river itself. If possible, sediments that are dredged at critical sections should be re-inserted into the river to decrease the sediment deficit.

3. Sediment quality

The characterisation of sediment quality in the Danube is primarily based on the results of the Danube Surveys (JDS1 and 2). During JDS1, significant concentrations of 4-iso-nonylphenol and di[2-ethyl-hexyl]phthalate were found in bottom sediments as well as in suspended solids (from a few µg/kg up to more than 100 mg/kg).

During JDS2, polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs) and dioxin-like polychlorinated biphenyls (PCBs) were more than one order of magnitude lower in all compartments when compared to the Elbe River and only one site (downstream of Pancevo) slightly exceeded the *safe sediment value* for PCDD/Fs. PCBs did not exceed the related German quality standards for sediment. Polybrominated diphenylethers (PBDEs) concentrations in the Danube suspended particulate matter (SPM) were an order of magnitude lower than in Dutch rivers.

Comparing the concentrations of polyaromatic hydrocarbons (PAH) analysed during JDS2 with the proposed EU environmental quality standards (EQS) for suspended solids, the results indicated that even the maximum concentrations recorded were far below the recommended limit values i.e. the maximum concentration of Benzo(a)pyrene was more than 20-times less than the EQS, and the concentration of Benzo(k)fluoranthene was about one-fifth of the proposed EQS for SPM. The most abundant PAH compounds in solid phase during JDS2 were fluoranthene and pyrene. The results of the Aquaterra survey in 2004 for PAHs however showed that fluoranthene frequently exceeded the proposed EU freshwater quality standard for sediment in the upper part of the surveyed reach (down to rkm 1262).

As regards pollution of the Danube sediment by the organochlorinated pesticides, JDS2 results from 2007 show an improvement when compared to JDS1 in 2001, not only in terms of the maximum concentrations recorded but mainly regarding the number of detected pesticides. Only for aldrin, chlorpyrifos, o,p'-DDD, p,p'DDE, o.p'-DDT, p,p-DDT, dieldrin, isodrin and the sum of trichlorbenzenes could concentrations above the limit of quantification be found at several JDS2 sampling sites. While aldrin and isodrin were detected in the upper Danube reach, elevated concentrations of other organochlorinated pesticides were found at only a few sampling sites in the mid and lower Danube reach.

Besides the ongoing degradation of these compounds, their reduction can also be explained by "dilution" by less polluted or unpolluted fresh sediment and the re-suspension, mixing and transport processes during the flood event in the time span between the two surveys. Although the results of the two surveys provide insufficient data to derive a clear trend in sediment pollution of the Danube River, an improvement seems to be evident for the organochlorinated pesticides analysed in 2001 and 2007.

The results of analysis of heavy metals in the sediment samples collected during the JDS1 showed that the concentrations of arsenic, cadmium, copper, nickel, zinc and lead (in tributaries only) were above the applied quality targets at more than one-third of the sampling points (German quality targets were used for this evaluation). Analysis of heavy metals in sediments and SPM during JDS2 revealed an influence from the Tisza and Sava increasing the concentration of cadmium and lead along the lower Danube reach. Increased concentrations of mercury were found in the tributaries Vah and Velika Morava. The longitudinal profile of nickel clearly showed a significant increase downstream of the confluences of the Sava, Tisza and Velika Morava.

4. Reference:

1. WWF (2008): Assessment of the balance and management of sediments of the Danube Waterway (Final Draft)