Uncertainty assessment on erosion of cohesive sediment in the Upper Rhine: Implications for sediment management

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Introduction: The Rhine is one of the most important waterways in the world. To generate energy and secure navigation, the Upper Rhine between Basel and Iffezheim has been impounded by 10 dams. The dams interrupt the sediment continuity along the Rhine and retain large amounts of sediment in the reservoirs upstream of these dams. Due to historic emissions of particle-bound micropollutants, the fine sediments that are deposited in the reservoirs are highly contaminated increasing the costs of maintenance dredging. Effective sediment management in the Upper Rhine therefore requires a detailed understanding of the sediment dynamics in the Upper Rhine. Here, we present results of an uncertainty assessment on the risk of erosion of cohesive sediments in the Upper Rhine and discuss implications for the effective sediment management.

Methods: The uncertainty assessment is based on the measurement of 350 bulk densities, grain size distributions, critical shear stresses (τ_c) and erosion rates (E). Sediment samples were taken from 12 sediment cores from the top 1m of the cohesive sediments in the Iffezheim reservoir. τ_c and E were estimated using the SETEG erosion flume of the University of Stuttgart [1]. Based on the erosion law $E = M_0(\tau_b/\tau_c - 1)$ [Eq.1] (where $\tau_b$is the bed shear stress), we estimated the erodibility M_0 of each sediment sample. Using the frequency distributions of these measurements and bootstrap regression, we analyzed the uncertainty of the critical shear stresses and of the erodibility.

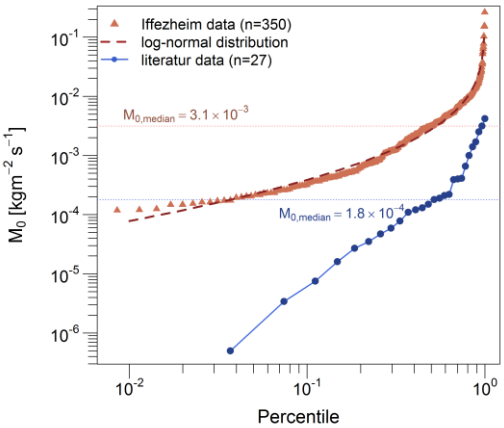

Fig. 1: Frequency distribution of measured erodibility in the Iffezheim reservoir.

In addition to the uncertainty assessment of the measured τ_c and E, we evaluated the impact of the uncertainties on the modelling of bed level changes of the Iffezheim reservoir. Therefore, we developed a vertical 1D-model that simulates the bed evolution of the Iffezheim reservoir considering sediment settling, consolidation and erosion (for details see [2]).

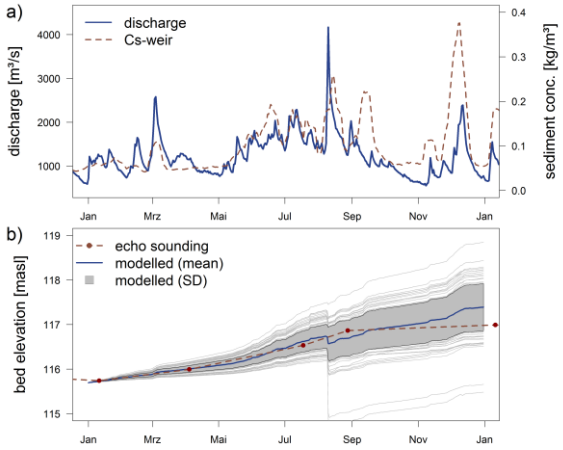

Fig. 2: Top: Discharge and sediment concentration at the Iffezheim reservoir in 2007. Bottom: Modelled bed evolution using 150 model runs.

Results: The estimated erodibilities range over several orders of magnitude (from ~10-4 to > 10-1 kg $m^{-1}s^{-1}$) (Fig.1). The comparison of measured and calculated erosion rates using [Eq.1] show a very low predictability (coefficient of variation of 1.01).
The large uncertainty associated with the estimation of the model parameters (considering sediment settling, consolidation and esp. erosion) results in a large variability of the modelled bed evolution of covering ~ 1m/a (Fig.2).

Discussion: Due to our limited knowledge of the dynamics of cohesive sediments (including settling, consolidation and erosion), the prediction of the fate of cohesive sediments in reservoirs is very uncertain. The uncertainty needs to be considered for sediment management strategies. Probabilistic approaches using low complexity models are an efficient tool to estimate the uncertainties related to the risk of erosion.

References: [1] Noack et al. (2015), *Water* 7: 5061-5077, [2] Hoffmann et al. (accept.) *Int J River Basin*