Model Based Estimation of Contaminated Sediment Dynamics in Groyne Fields along the River Elbe

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Introduction: Even though ongoing emissions of contaminants are recently reduced in European rivers [1], environmental issue of river water quality is still not abating. The exploration of contaminated deposits (i.e., historical sediments) and their mobility are key issues in sediment management strategy and planning. Re-suspension of contaminated sediments impacts the water quality and thus, it is important to determine the erosion probability of such deposits.
This research is focused on the River Elbe deposits in groyne fields and their erosion probability. Highly contaminated deposits in the groyne fields originate presumably from the tributary Mulde, which discharges high concentrations of arsenic and lead into the Elbe [3]. The erodibility of the sediments and associated contaminants in groyne fields is difficult to predict due to complex interaction of the physical, chemical and biological sediment properties [2], as well as lack of information. Therefore, in an engineering practice the values for erosion parameters are usually assumed to be constant despite their high spatial and temporal variability, which leads to their large uncertainty. The goal of the presented study is to compare a conservative approach assuming constant critical erosion shear stress [5] and an innovative statistical approach which takes the critical erosion shear stress as a random variable. Furthermore, a quantification of an effective value of the critical erosion shear stress and its applicability in numerical models are estimated as well.

Methods: During two years measuring campaign undisturbed sediment cores were taken in groyne fields of the River Elbe. The samples were taken in three groyne fields along the river course, at various spots within a groyne field, and in different season of a year. Depth orientated critical erosion shear stress was measured using the SETEG-System [4]. The measured data showed high spatial and temporal variability. Therefore, it was very difficult to assign the effective value of the critical erosion shear stress, which represents each groyne field in a river section and has to be used in numerical models.
Based on a theoretical distribution of the measured data, random values of the critical erosion shear stress were generated for each groyne filed in a simulated domain of the 112 km long reach of the Elbe, from Wittenberg to Magdeburg. The numerical simulations were performed by a 1D multi-strip model, which predicts suspended sediment transport in rivers trained by groynes [6]. Flood discharge of 1790 m^3/s was applied in the Elbe in order to determine total eroded mass. The statistical approach, which treats the critical erosion shear stress as random variable, was compared to the deterministic conservative approach, which assumes that erosion can be estimated by using a constant value of the critical erosion shear stress. Therefore, different values of the critical erosion shear stress were applied: (1) mean value (3.05 Pa), (2) minimum value (0.28 Pa), (3) mean value plus standard deviation (6.24 Pa), and (4) randomly longitudinally distributed values (large number of realizations allows erosion probability estimation).

Results and Discussion: The conservative approach assumes that erosion can be estimated by using a single value of the critical erosion shear stress, ignoring the fact that with on going erosion deeper layers with different value of the parameter will be exposed to flow. The statistical analysis gave the effective value of the critical erosion shear stress to be smaller compared to the mean measured value. The results showed that the conservative method for determining erosion lead to underestimates of groyne field erosion.

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