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The use of heavy metal top soil concentrations for the validation of overbank floodplain sedimentation models

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In floodplains of lowland rivers, the transport, sedimentation, and remobilization of fine sediments is highly variable in space and time. Therefore, it is often difficult to validate sediment transport models due to the lack of appropriate data. The objective of this study is to show that heavy metal concentrations in the top soil (upper 15 cm) of a highly polluted floodplain are related to the deposition of fine sediments and thus can be used to assess the plausibility of a two-dimensional (2D) hydraulic and sediment transport model. In a floodplain, heavy metals are bonded to fine sediments, and the deposition of heavy metals originates from a long history of floods. Heavy metal concentrations can be used as a time-integrated indicator of sedimentation, if during a defined period of heavy metal contamination the total deposition of fine sediments is less than a defined topsoil sampling depth.
We provided evidence for this hypothesis studying a 45km^2-floodplain of River Mulde (Germany). For the assessment of heavy metal top soil concentrations, 126 samples were available. Hydraulics, sedimentation patterns, and concentrations of particle-bonded pollutants were calculated with a 2D computational fluid dynamics (CFD) model (TELEMAC 2D). The calibration of critical velocities of sedimentation and erosion of the model was based on sediment trap exposures during a flood event with a ten-year recurrence interval (Schulz et al. 2009). The calculated sedimentation of the calibrated model was subdivided into three classes: low sedimentation (<0.1 mm), medium sedimentation (0.1 mm < sedimentation < 1 mm), and high sedimentation (> 1mm). Heavy metal concentrations of the floodplain soil were classified according to these simulated spatially distributed sedimentation classes.
The analysis of the measured and modelled values clearly showed that the mean values of the classified concentrations of arsenic (As), lead (Pb), cadmium (Cd), and zinc (Zn) were increasing with increasing simulated sedimentation rates. Cd and Zn showed the clearest correlation between top soil concentration and simulated sedimentation.
Although the presented method allows only a semi-quantitative validation of the model, the plausibility of the results of the CFD model could be demonstrated. The method has the major advantage that single sampling campaigns of topsoils are much less time-consuming than event-based sampling methods, such as the use of sediment traps. The advantages and disadvantages of the proposed method are discussed in detail.

Reference

Schulz M., Büttner O., Baborowski M., Matthies M., Böhme M. & von Tümpling W (2009)
A dynamic model to simulate arsenic, lead, and mercury contamination in the terrestrial environment during extreme fluvial high waters. CLEAN - Soil, Air, Water, Vol. 37 Issue 3, 209-217, doi: 10.1002/clen.200900013