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Understanding transport paths of fluvial suspended sediments - monitoring polluted sediments of an incident

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The downstream routing of suspended particulate matter (SPM) through river systems strongly depends on discharge conditions and involves transport times and periods of sediment resting in deposits, e.g. in areas with low flow velocities adjacent to the main channel. Knowledge about transport velocities and the residence time of (contaminated) SPM is an important factor for the sediment management. It is, however, difficult to estimate the average residence times and thus average transport velocities of SPM within rivers.

In this study, particle bound polychlorinated biphenyls (PCB), which were released by an incident in the Elbe river (Central Europe) in spring 2015, could be used as unique tracer for transport pathways of SPM along the entire river stretch (over 700 km length). In 2015 the Elbe River was characterized by low-discharge conditions. Thus, no SPM was exported on flood plainsduring this period, limiting SPM transport, deposition and remobilization to the river channel.

The incident was monitored by concentration measurements of seven indicator PCB congeners along the inland part of the Elbe River as well as in the Elbe estuary. Data from ten monitoring stations (settling tanks) were analyzed. It is shown that the ratio of high versus low chlorinated PCB congeners (PCB6 ratio) is a suitable tracer to distinguish the PCB load of the incident from the long-term background signal. We demonstrate that both the load of PCB as well as its chemical fingerprint, the PCB6 ratio, allows the estimation of transport durations for the transport processes involved.

Interestingly, the reduction of total PCB tagged SPM load within the first 514 km downstream of the incident site indicates that roughly 75% of the annual SPM load (of the most upstream station located 43 km downstream of the incident site) is stored in the sediments of the Elbe River. This suggests that suspended sediment in transport enters channel-bed storage after a relatively short distance during low flow conditions. It is particularly surprising that already 25% of the PCBs are deposited between the two upstream stations that are characterized by limited floodplains and a steep channel gradient between 0.26 and 0.28 m/km. However, while PCB fluxes decrease, SPM fluxes increase. Between these two stations the suspension freight increases from 0.12 to 0.18 (2015) and from 0.09 to 0.12 Mt/a (2016).

We therefore discuss the question if the transport of PCB is decoupled from the transport of SPM and potential locations where SPM can be stored. Therefore, the trap efficiencies for both parameters, PCB and SPM, are estimated to allow for a cross check of the retention rates of PCB and SPM, respectively. A mathematical concept based on reservoir theory is applied to model residence time of PCB and SPM during non-stationary conditions section by section between the individual measurement stations. Once SPM settles, significant storage can occur over decadal time scales. This might strongly complicate sediment management issues in the future.