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Impact of century flood on the phosphorus stock and mobilization in the Upper Danube

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During the past two decades Germany and Austria have undertaken considerable efforts to reduce their phosphorus emissions into the Danube River. In the same period the Upper Danube Basin was also affected by extreme hydrological events, the most notable of which being two large floods in August 2002 and June 2013. This period of combined anthropogenic changes and extreme hydrological conditions represents an exceptional opportunity for exploring interweaving processes and causalities in a large river. In this work time series (1991-2013) of concentrations of total and soluble reactive phosphorus (TP, SRP) and suspended sediments at the inflow and outflow of the Austrian Danube are statistically analyzed per categories of flow level. Moreover, yearly loads are calculated with three different methods and their development in time is examined in the context of emission loads and hydrological regimes. The analysis reveals that a very pronounced and long-lasting decline of the TP concentration took place after the 2002 flood, which was still visible during the 2013 event. The mean TP concentrations before 2002 varied from 0.07 mg/l at low flows to 0.54 mg/l at very high flows. After the 2002 flood the range at all flow levels was reduced to 0.05-0.08 mg/l. The shift affecting high flow conditions could be related neither to reduced emissions nor to reduced turbidity. Therefore the most plausible explanation is that the flood scoured the river bed causing a depletion of the phosphorus rich sediments (primarily algae mass) and that the recovery of this pool was delayed by the low availability of dissolved phosphorus, as a result of reduced point emissions. The development in time of the TP riverine loads offers further evidence of this hypothesis. The presence of a pool of phosphorus rich sediments in the river, derived from the sedimentation of algae mass, maintained during the 1990s a high level of loads and neutralized the efforts of reduction of point discharges, although these were translated into a decline of SRP and TP concentration at baseflow conditions. After the 2002 flood the annual loads experienced a very sharp and enduring decline, provoked by a reduced phosphorus mobilization, since the level of maximum discharges did not change with respect to the previous period. These conclusions are strengthened by the fact that inflow and outflow present very similar and consistent results, both in terms of concentrations and loads. This contribution offers new evidence of the large impact that flood events can exert not only on the episodic transport of riverine loads, but also on the in-stream phosphorus stock and on its mobilization. It flags the importance of better understanding the role that retention, floods and in-stream stocks play in terms of altering the phosphorus mobilization in rivers, either interfering or amplifying the anthropogenically induced changes. This is highly relevant in order to improve the river basin models and to interpret correctly monitoring data in relation to the assessment of the performance of environmental management measures, especially in such a transboundary context as the Danube River.